

Space Program Operations Contract

SPACE SHUTTLE ORBITER OPERATIONAL LEVEL C FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS GUIDANCE, NAVIGATION AND CONTROL PART A

ENTRY THROUGH LANDING GUIDANCE

PREPARED BY THE BOEING COMPANY
Space Exploration

Under Subcontract 6000132079, PDRD P1433q

December 14, 2007

DRD 1.4.3.3-q

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G4.8	ENTRY GUID
G4.9	TAEM GUID
G4.204	GRTLS GUID

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G4.10	A/L GUID
G4.234	GRTLS A/L GUID

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FOREWORD

The primary avionics software system (PASS) requirements for the computer programs that execute in the Shuttle general purpose computers (GPC's) are specified in the Computer Program Development Specifications (CPDS's) and the Functional Subsystem Software Requirements (FSSR) documents. The requirements are specified at three levels:

Level A CPDS – System-level constraints and capabilities

Level B CPDS – Functional requirements

Level C FSSR – Detailed-level requirements

The Level A CPDS specifies system-level constraints and capabilities that are not oriented toward any particular program end item. The Level B CPDS specifies system-level requirements for guidance, navigation, and control (GN&C) and detailed requirements for systems management (SM) and vehicle utility (VU). The Level C FSSR's specify the detailed requirements for GN&C and display/controls. The Level C reconfigurable requirements are specified in the systems management and payload documents. The Level A, Level B, and Level C requirements documents are listed in Section 2, Applicable Documents.

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DOCUMENT CHANGE RECORD

The following tabulation summarizes the change activity associated with this document.

DOCUMENT CHANGE RECORD			
Issue and Date	Change Summary/Effectivity		
OI-34 Release December 14, 2007	This baseline release for effectivity OI-34 and subs includes:		
	<u>CR</u>	<u>OI</u>	<u>Title</u>
	93017G	33	Baseline RSS99D0100 with Expanded Downlist
	93174A	33	Improved GRTLS TAEM "Alpha Trap"

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CHANGE REQUEST SUMMARY

The following tabulation lists the paragraphs, tables (T), and figures (F) that have been changed as a result of approved change requests for this release. Changes incorporated prior to this release are listed in Appendix R. Changes from approved change requests (CRs) to this document are indicated by a change bar in the outer margin of the changed page.

CHANGE REQUEST SUMMARY			
Paragraph	CR No.	OI	CR Title
1.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.5.4-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.5.4-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.6.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.6.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.7.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.7.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.8.2.8	93174A	33	Improved GRTLS TAEM "Alpha Trap"
4.8.2.8-2.(T)	93174A	33	Improved GRTLS TAEM "Alpha Trap"
4.8.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.8.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.8.3-3.(T)	93174A	33	Improved GRTLS TAEM "Alpha Trap"
4.9.3-1.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist
4.9.3-2.(T)	93017G	33	Baseline RSS99D0100 with Expanded Downlist

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the Guidance Level C document is to present implementation details and formulations of the Guidance Level B functional requirements for the orbiter guidance, navigation, and control (GN&C) flight software.

1.2 SCOPE

This document contains the detailed requirements and formulations for those guidance principal functions that are operative during entry through landing.

Included functions are specified in the Level B, GN&C Functional Requirements CPDS and consist of the following:

- Entry Guidance (P.F. 4.8)
- Terminal Area Energy Management (TAEM) Guidance (P.F. 4.9)
- Approach and Landing (A/L) Guidance (P.F. 4.10)
- Glide Return-to-Launch-Site (GRTLS) TAEM Guidance (P.F. 4.204)
- GRTLS Approach and Landing (GRTLS A/L) Guidance (P.F. 4.234)

This document does not discuss performance requirements and results (although it is recognized that the software requirements are derived from performance requirements and vehicle constraints). Dispersion tolerances, vehicle constraints, and guidance performance requirements at the entry-TAEM and TAEM-A/L interfaces and at touchdown are or will be included in the Flight Control System Data Book, Vol. II, Orbiter, SD 73-SH-0097-2E.

1.3 ORGANIZATION

This document is organized into the following sections:

- 1.0 Introduction
- 2.0 Applicable Documents
- 3.0 Mission and Guidance Phases
- 4.0 Detail Requirements
- 5.0 Supplementary Material

Section 1 defines the purpose, scope, and organization of this document. Section 2 lists applicable references. Section 3 describes the mission and guidance phases. Section 4 specifies detailed software requirements. It also contains applicable tables (IDD inputs/outputs, I-Loads, K-Loads, and Constants) located at the end of each Principal Function. Section 5 provides supplemental material such as parameters and logic flow, coordinate systems, and glossary.

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The initial definitions of equation parameter values are contained in Section 5 tables. These represent the parameter values for the compilation of the programs. Most values are zero except for values specified in Initialization Requirements, paragraph D, of Sections 4.5, 4.6, 4.7, and 4.8.

Detailed guidance requirements for entry, TAEM, A/L, GRTLS TAEM, and GRTLS A/L phases are presented in Sections 4.5, 4.6, 4.7, 4.8, and 4.9.

The automated IDD tables provided herein define signal (parameter) interface requirements either between hardware (LRU) and software elements or between software elements and other software elements. A GN&C software element is either a sequenced principal function (PF), crew generated specialist/display function, or an OPS display function. In the event of a conflict between the IDD tables and other internal text input/output tables, the SASCB data base-controlled IDD tables take precedence.

The following table defines the data elements found in the IDD input/output, I-Load, K-Load, and Constant tables for each principal function.

Table 1.3-1. Parameter Element Description		
Title	Definition	Valid Entries
CAT	Category of the I-Load (**Note)	Three alphanumeric characters: the first character must be alphabetic.
D	Dependency of the I-Load	D = Design M = Mission L = LRU
DESCRIPTION	Parameter description of the K-Load or Constant.	A string of ≤ 64 characters.
DESTINATION	Destination of the output parameter	Abbreviated functional titles. (***) Note)
DT or DATA TYPE	Data Type	* See reference (1) for valid I-Load, K-Load and Constant data types. * See reference (2) for valid IDD data types for parameters with destination TLM. * See reference (3) for valid IDD data types for all other parameters.
ENG UNITS or UNITS	Engineering Units	* See reference (1) for valid I-Load, K-Load and Constant units. * See reference (2) for valid IDD units for parameters with destination TLM. * See reference (3) for valid IDD units for all other parameters.
FSSR NAME	Requirements parameter name	A string (with no embedded blanks) of ≤ 32 characters consisting of alphanumerics, underscores, parenthesis, commas and slashes. Parenthesis are used for array elements. Commas separate the different indices of multidimensional arrays. Slashes are used to separate multiple names used for a single MSID.
LAST CR	The last CR affecting the parameter	5 digit number with an alphabetic revision letter.

Table 1.3-1. Parameter Element Description		
Title	Definition	Valid Entries
MC	Memory Configuration	00 = Generic 01 = GN1 Ascent/GN6 RTLS 02 = GN2 Orbit 03 = GN3 Entry 04 = SM2 On-Orbit 05 = SM4 Orbit P/L 06 = P/L9 MMU 07 = Not Assigned 08 = GN8 On-Orbit C/O 09 = GN9 Preflight
MSID or M/S ID	Measurement/Stimulus Identification	Maximum of 10 alphanumeric characters. * See reference (3) for specifications
NOMENCLATURE	Parameter description of the IDD parameter.	String of ≤ 34 characters (including underscores and blank spaces).
PR or PREC	Precision	D, DP = Double S, SP = Single
REV	Revision indicator	An asterisk (*) indicates changes for the current OI version.
SOURCE	Origin of the input parameter	Abbreviated functional titles.
S	Software Utilization	C = Common P = Primary A = BFS Converted B = BFS Unique X = BFS Derived
PR FCTN	Cross reference of the principal function identifiers that are applicable to this parameter.	See Level B GN&C CPDS SS-P-0002-510
VALUE	The value of the K-Load or Constant	* See reference (1) for valid value formats.
<p>* References: (1) JSC 19350 I-Load Requirements Document Volume I (2) SS-P-0002-140 Level A SS Downlist/Uplink CPDS (3) JSC 18206 Shuttle Data Integration Plan Volume III MAST II/STAR Deliverable Products.</p> <p>** Note For additional information on any I-Load, contact the I-Load owner defined in CR98032, JSC, USA, and Boeing I-Load Owner Assignments</p> <p>*** Note IDD output (source) tables which reflect parameters going to input (destination) "TLM" shall not be interpreted as a signal actually being downlisted. The parameter is only available for downlist in COMPOOL and does not appear in a downlist format. Parameters actually on the downlist will be designated with a destination denoting the downlist Format with a Rate Code. The Rate Code legend appears at the end of each FSSR data table. To complete the downlist information, Parent MSIDs (indicated by a 'P' in the 9th character of the MSID) are now included in the software function output data tables in which a Child MSID already appears. A Parent MSID will have the same downlist destinations as its Child(ren) MSID(s).</p>		

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2.0 APPLICABLE DOCUMENTS

2.1 LEVEL A DOCUMENTS

- SS-P-0002-140 Shuttle Downlist/Uplink Software Requirements
- SS-P-0002-150 Shuttle Launch Data Bus Software Interface Requirements
- SS-P-0002-170 Shuttle Systems Level Requirements, Software

2.2 LEVEL B DOCUMENTS

- SS-P-0002-510 Shuttle Functional Level Requirements, GN&C
- SS-P-0002-550 Shuttle Functional Level Requirements, Vehicle Utility
- SS-P-0002-580 Shuttle Functional Level Requirements, Systems Management

2.3 LEVEL C DOCUMENTS

- STS 83-0001 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Entry Through Landing Guidance
- STS 83-0002 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance Ascent/RTLS
- STS 83-0003 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part A, Guidance On-Orbit/Deorbit
- STS 83-0004 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, Entry Through Landing Navigation
- STS 83-0005 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, Navigation Ascent/RTLS
- STS 83-0006 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part B, On-Orbit Navigation
- STS 83-0007 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part C, Flight Control Entry – GRTLS
- STS 83-0008 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part C, Flight Control Volume 1, Ascent Flight Phase, Volume 2, Ascent
- STS 83-0009 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part C, Flight Control Orbit DAP
- STS 83-0010 Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part D, Redundancy Management

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STS 83-0013	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part E, Inertial Measurement Unit Subsystem Operating Program
STS 83-0014	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part E, Volume 1, Navigation Aids Subsystem Operating Program, Volume 2, Star Tracker Subsystem Operating Program
STS 83-0015	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part E, Subsystem Operating Programs, FC Sensor/Controller
STS 83-0016	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Part E, Subsystem Operating Programs, FC Effector
STS 87-0017	Operational Flight Level C, Functional Subsystem Software Requirements; Remote Manipulator System
STS 83-0020	Operational Flight Level C, Functional Subsystem Software Requirements; Displays and Controls
STS 83-0026	Operational Flight Level C, Functional Subsystem Software Requirements; Guidance, Navigation, and Control, Sequencing
JSC-19350	Shuttle Flight Software Initialization Load <ul style="list-style-type: none">• Volume I General Requirements• Volume II Mission I-Load Requirements
JSC-19478	Payload Management, Level C Flight Software Requirements
JSC-19590	Systems Management, Level C Flight Software Requirements

2.4 ICD DOCUMENTS

ICD 3-1011-02	GPC/DEU ICD
ICD 2-1S001	PASS/BFS ICD

In the event of a conflict between the documents referenced herein and the contents of this specification, the precedence shall be determined as defined in paragraph 1.3 of CPDS SS-P-0002-170, Volume 1, System Level Requirements, Software.

3.0 ENTRY THROUGH LANDING MISSION AND GUIDANCE PHASE DESCRIPTIONS

3.1 MISSION DESCRIPTION

The entry through landing flight profile is shown schematically in Figure 3.1-1. This flight profile encompasses two major modes with the following three phases:

1. Entry (MM304)

This major mode contains all functions necessary to monitor, guide, and control the vehicle from entry initiation (ref: Level B CPDS Event E16) to attainment of the TAEM interface.

The entry major mode will be exited by a relative velocity dependent, automatic or crew initiated transition to the TAEM major mode (ref: Level B CPDS Event E21).

2. TAEM (MM305)

This phase of Major Mode 305 contains all functions necessary to monitor, guide, and control the vehicle from initiation of the Terminal Area Energy Management (TAEM) phase to the Approach / Landing interface. TAEM will be exited by an automatic transition to the approach and landing phase (ref: Level B CPDS Event E22A).

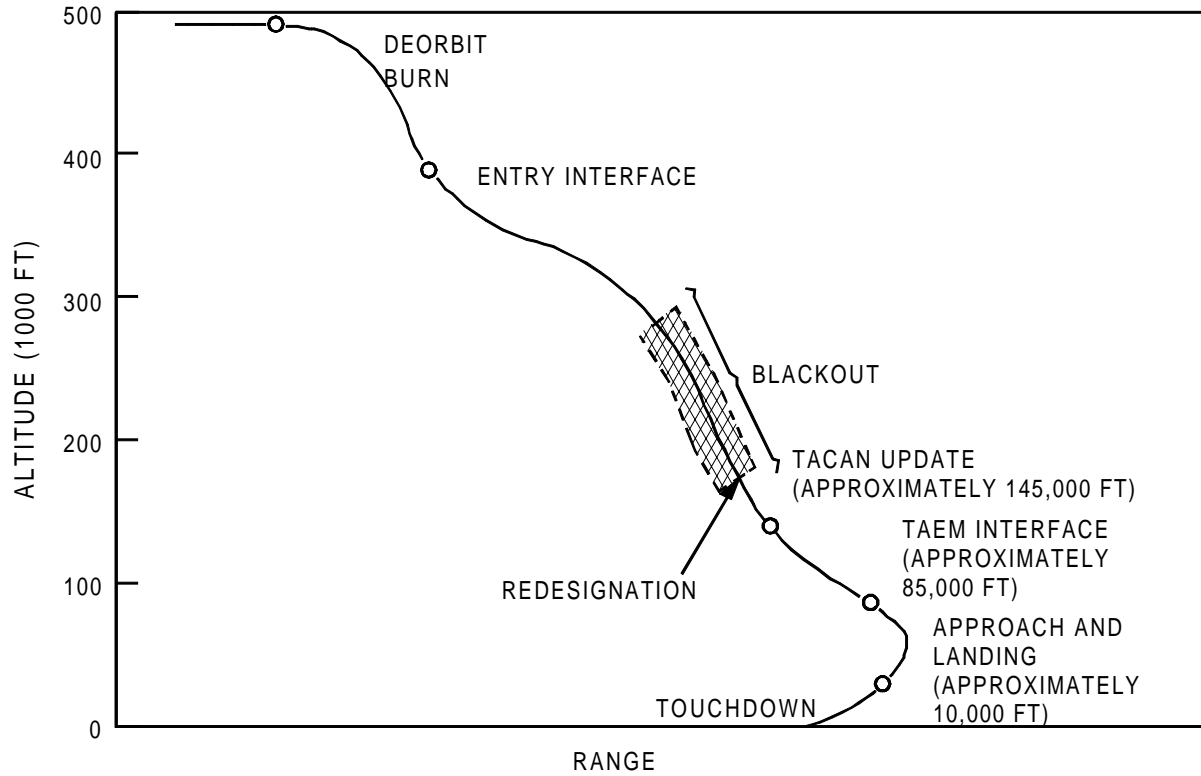
3. Approach/Landing (MM305)

This phase of Major Mode 305 contains all the functions necessary to monitor, guide, and control the vehicle from initiation of the approach and landing phase to a stop on the runway.

The post deorbit initiation of the entry major mode normally occurs prior to the 400,000 foot entry interface altitude, before any aerodynamic forces are sensed, by crew action. (Note: for declared, intact TAL aborts, initiation of the entry major mode will occur as part of the OPS 1 to OPS 3 transition requirements and should nominally occur at an altitude of approximately 350,000 feet.) This entry mode continues until the TAEM interface is reached. Entry guidance controls the range and heading flown during entry so at the entry-TAEM interface, the orbiter will be near one of the target loci sketched in Figure 3.1-2. The entry to TAEM transition will occur when a specified condition of velocity is satisfied as determined by entry guidance.

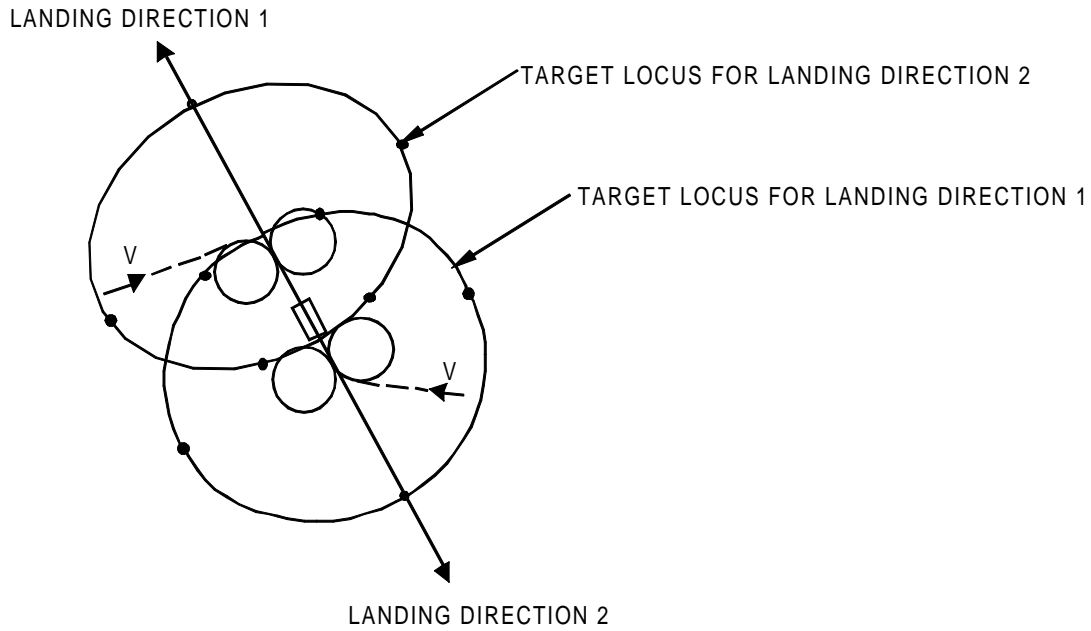
The TAEM phase of Major Mode 305 brings the orbiter to a final state near the runway centerline and the A/L steep glide slope. The TAEM-A/L transition logic is shown in Figure 3.1-3 (this figure is for information only). The A/L phase of Major Mode 305 brings the vehicle to touchdown and through rollout to a stop on the runway.

A generalized schematic of information flow through the guidance, navigation, and flight control loop is shown in Figure 3.1-4. The functions shown are performed in one form or another during all phases of Shuttle missions in which GN&C is active.



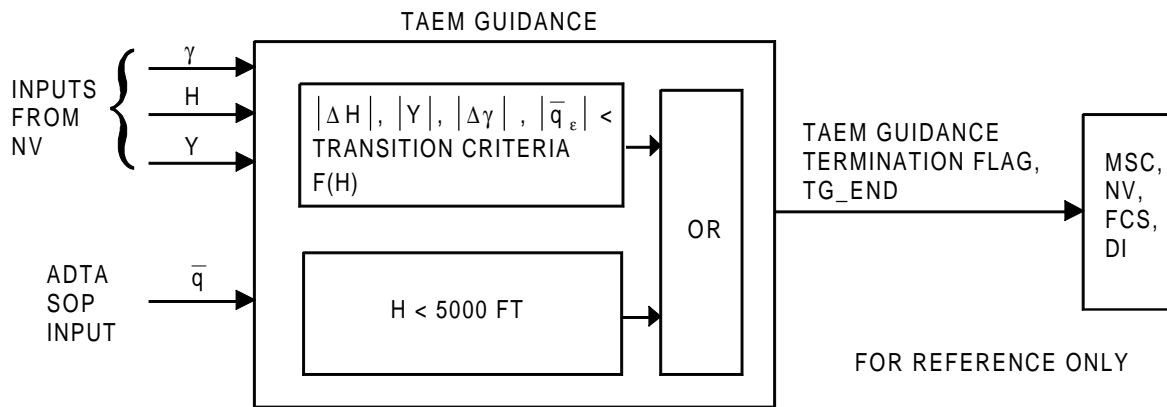
(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 3.1-1. Orbiter Entry Flight Profile



NOTE: STRAIGHT-IN TAEM HAC APPROACH TARGETING OPTION SHOWN FOR SIMPLICITY.

FIGURE 3.1-2. Targeting for Entry-TAEM Interface



NOTE:

- $\Delta\gamma$ = GROUND RELATIVE FLIGHT PATH ANGLE ERROR DEG
- H = ALTITUDE OF REAR WHEELS ABOVE RUNWAY FT
- Y = CROSS RANGE POSITION WRT RUNWAY FT
- ΔH = ALTITUDE ERROR, FT
- \bar{q}_e = DYNAMIC PRESSURE ERROR, PSF
- \bar{q} = DYNAMIC PRESSURE, PSF
- γ = GROUND RELATIVE FLIGHT PATH ANGLE, DEG

FIGURE 3.1-3. TAEM-to-A/L Transition Criteria

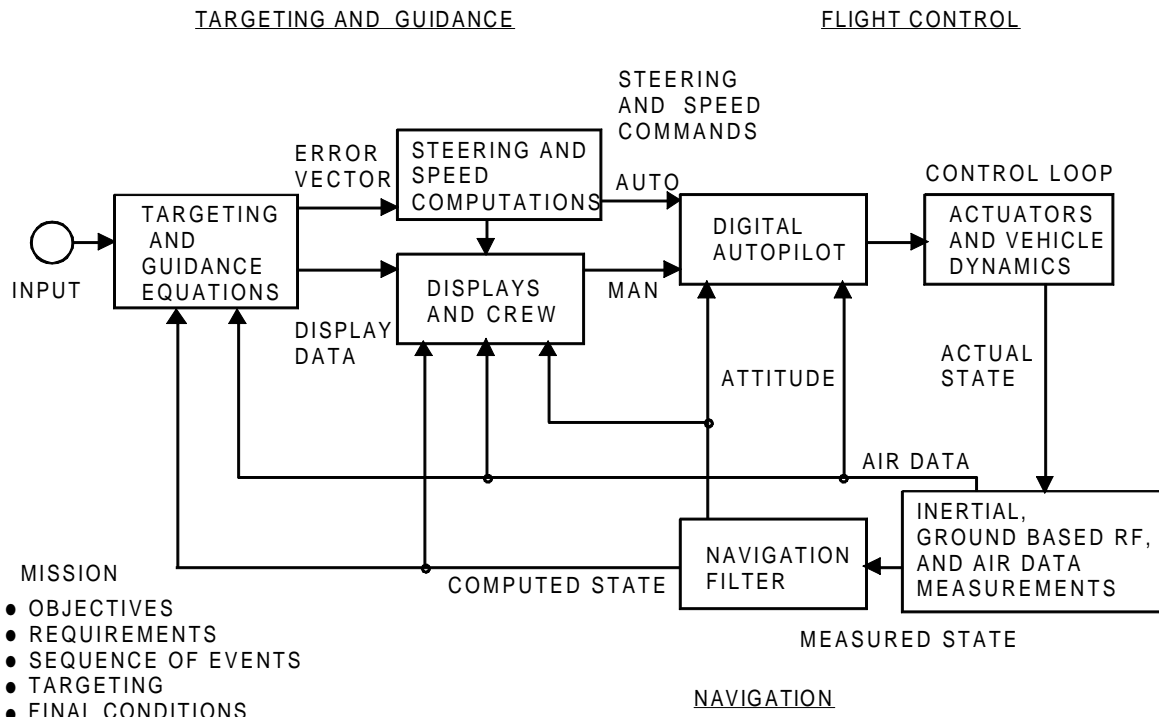


FIGURE 3.1-4. Guidance, Navigation, and Control Loop

3.2 GUIDANCE PHASES

The guidance function in each major mode is divided into several submodes, or phases, which are described in this section.

Entry guidance (Major Mode 304) is divided into five phases, as follows:

<u>Phase</u>	<u>Name</u>	<u>Description</u>
1	Pre-entry	Pre-entry is an attitude hold mode prior to atmospheric entry.
2	Temperature control	The temperature control phase defines an entry profile shape consistent with the TPS constraints during the high-heating part of entry.
3	Equilibrium glide	The equilibrium glide phase provides an entry profile that has the fundamental shape of equilibrium flight. It is used during the intermediate velocity region of entry.
4	Constant drag	The constant drag phase provides a profile shape consistent with control system limits.
5	Transition	The transition phase provides a profile shape consistent with the control system limits and guides the vehicle to the proper TAEM interface conditions.

During entry, range is controlled by drag modulation, while crossrange is controlled by roll angle reversals. A typical entry h-V profile showing the flight regime of the five phases is shown in Figure 3.2-1.

TAEM guidance (Major Mode 305) is divided into four flight phases:

<u>Phase</u>	<u>Name</u>	<u>Description</u>
0	S-turn	This optional mode for extreme high energy conditions is used only when approach and landing interface constraints cannot be met otherwise. The vehicle turns away from the target until sufficient energy is dissipated to allow a normal approach.
1	Acquisition	The vehicle turns until it is tangent to the selected heading alignment cone and continues until it reaches the cone.
2	Heading alignment	The heading alignment cone is followed until the orbiter is near the runway entry point.
3	Prefinal	The vehicle leaves the heading alignment spiral and rolls to acquire the runway centerline.

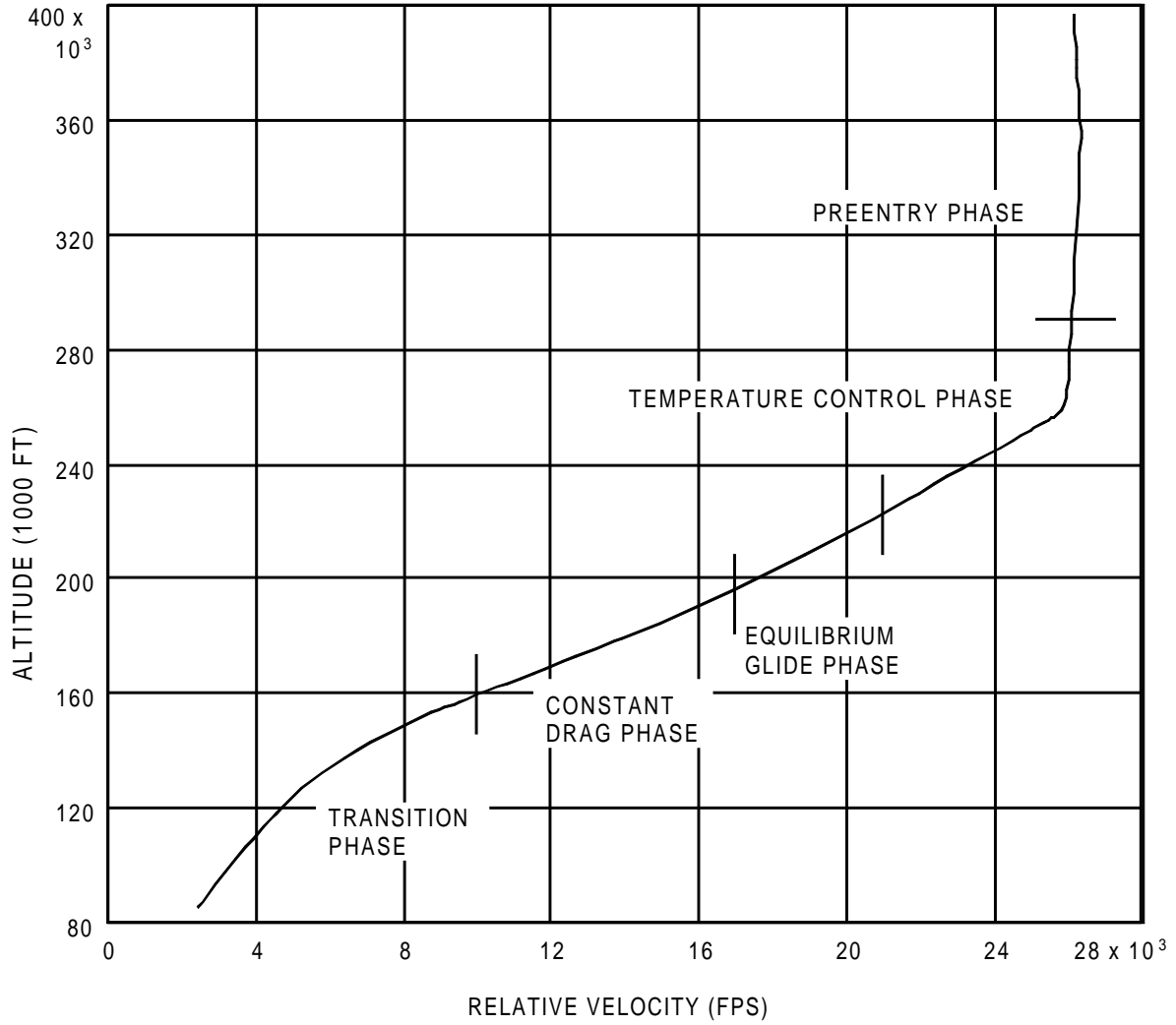
Figures 3.2-2A and 3.2-2B show the TAEM ground track geometry.

The approach and landing guidance (Major Mode 305) is divided into five flight phases:

<u>Phase</u>	<u>Name</u>	<u>Description</u>
1	Trajectory capture	Trajectory capture starts at the TAEM interface and continues to guidance lock-on to the steep glide slope.
2	Steep glide slope	The steep glide slope is tracked in elevation and azimuth.
3	Flare and shallow	Transition from the steep to the shallow glide slope is performed in preparation for landing.
4	Final flare	Final flare reduces the sink rate to near zero for touchdown.
5	Touch down and roll-out	The vehicle is directed along the runway centerline from flat turn until it comes to a complete stop.

Approach and landing (A/L) occurs essentially in the vertical plane containing the runway centerline. Figure 3.2-3 shows the A/L trajectory and flight phases.

GRTLS TAEM operations and flight phase descriptions are given in Section 4.8. GRTLS A/L operations are identical to those of entry (MM 305) A/L operations, as described above.



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 3.2-1. Entry Guidance Phases

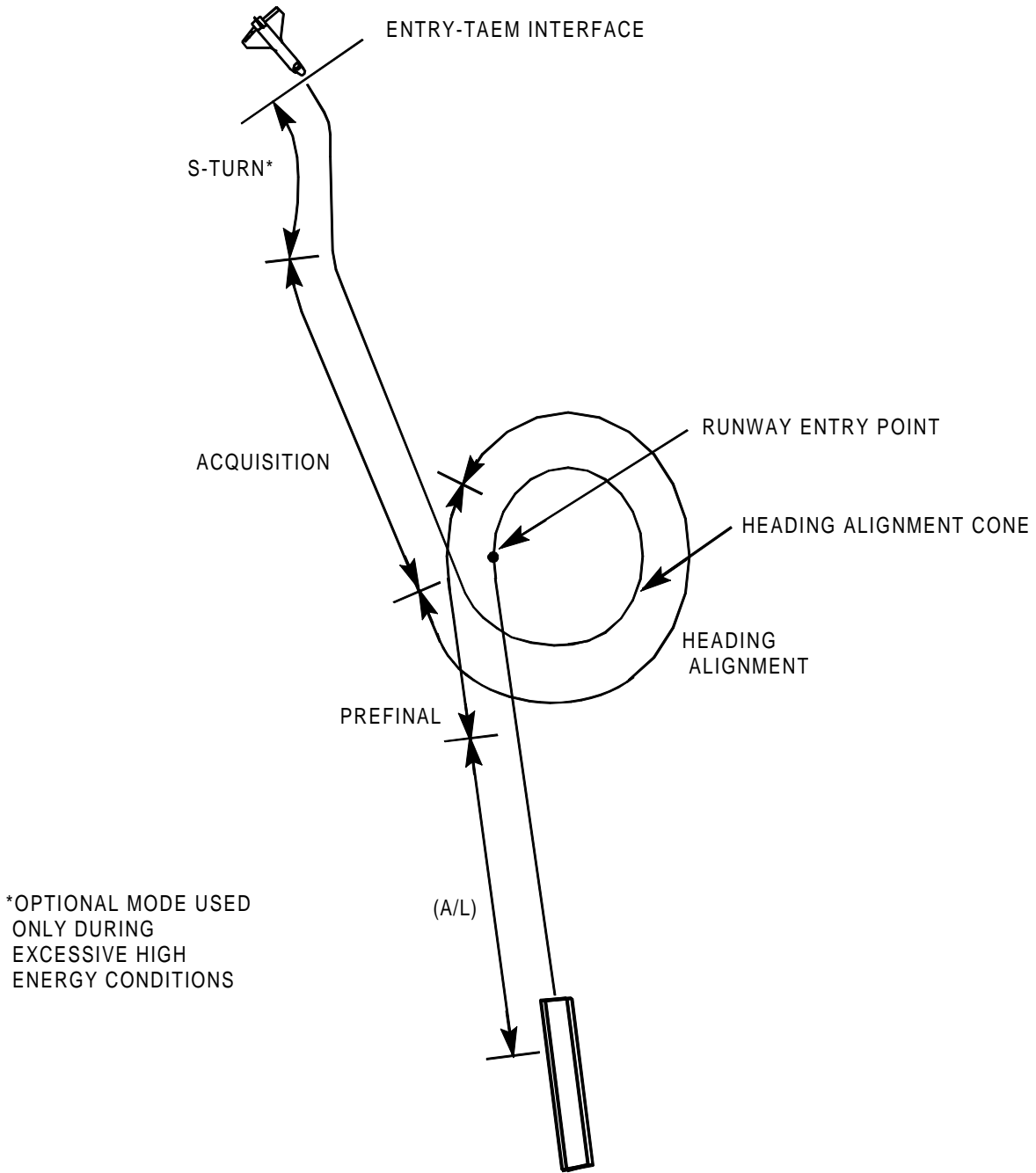


FIGURE 3.2-2A. TAEM Guidance Phases and Ground Track Geometry for Overhead Approach

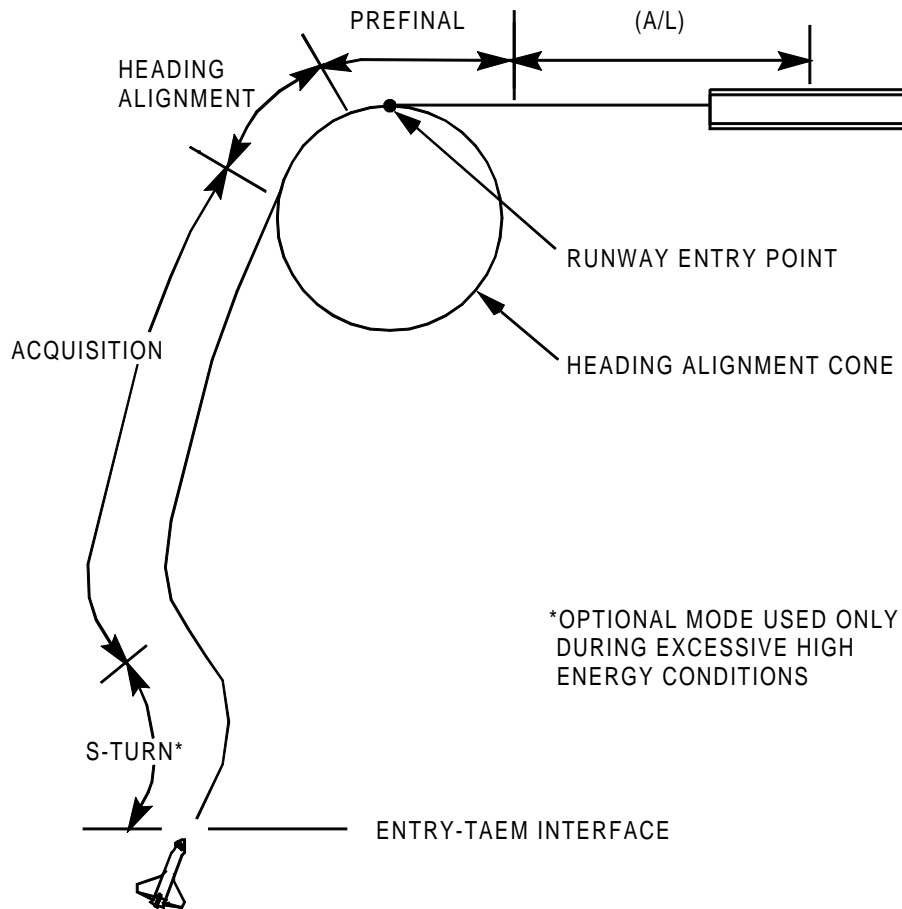


FIGURE 3.2-2B. TAEM Guidance Phases and Ground Track Geometry for Straight-In Approach

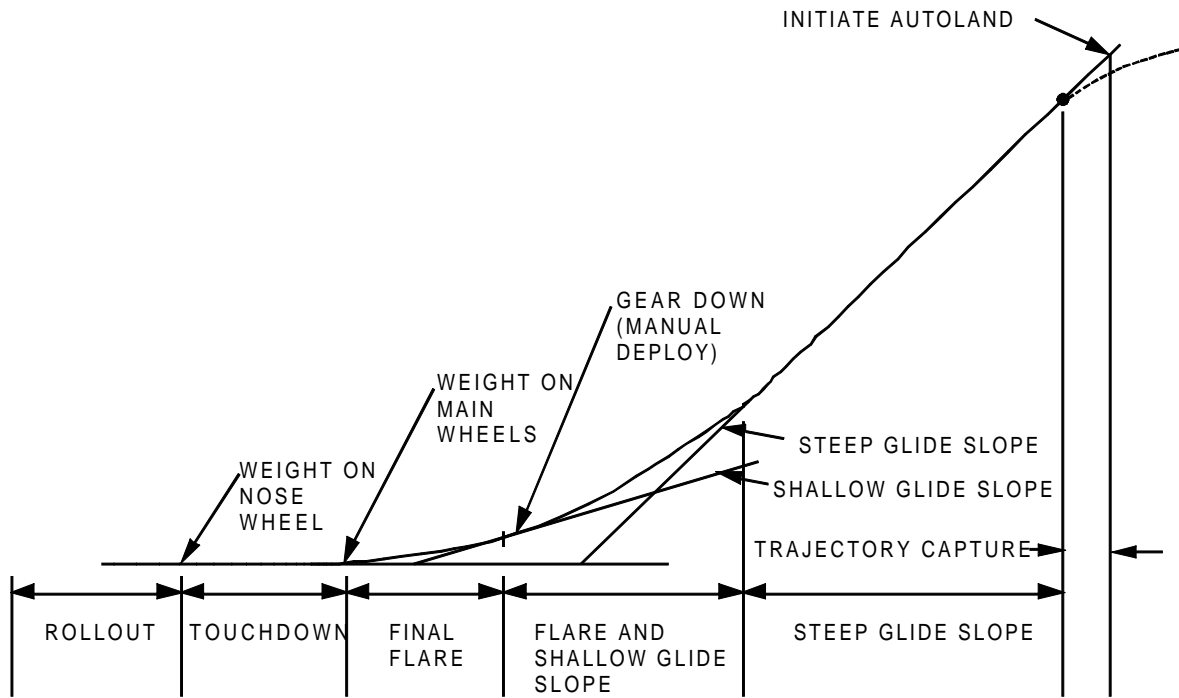


FIGURE 3.2-3. Approach and Landing Trajectory

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4.0 GUIDANCE SOFTWARE DETAILED FUNCTIONAL REQUIREMENTS

4.1 INTRODUCTION

4.1.1 Guidance, Navigation, and Control Software Overview

The operational flight program (OFP) represents the total computer program which operates in the orbiter general-purpose flight computer subsystem. The requirements for the OFP are specified at three levels: (A) system level, (B) functional level, and (C) detailed subsystem functional requirements. In addition, the Level B and C requirements are specified in separate documents for guidance, navigation, and control (GN&C), and for systems management (SM).

The GN&C major functions in the OFP are:

Guidance (GD)

Navigation (NV)

Flight control (FC)

Redundancy management (RM)

Subsystem operating programs (SOP)

Displays and controls (D&C)

Additional software major functions that interface with GN&C are the flight computer operating system (FCOS), systems management (SM), and checkout (CO).

This document contains the guidance specifications for GN&C Level C OFP requirements applicable to the entry through landing phases.

A block diagram of the relationships of the flight computer with other elements of the Shuttle system is illustrated in Figure 4.1-1.

4.1.2 Synopsis of Section 4

The rest of Section 4 presents the detailed guidance software requirements for the operational entry through landing mission phase. The subsections are:

4.1 Introduction

4.2 Traceability. Corresponding Level B and C section numbers are listed.

4.3 Parameter Tables. Section 4.3 references and describes tables within the detailed requirements sections that list the inputs, outputs, and I-loads/constants for each guidance function.

4.4 Guidance Execution Requirements. Guidance scheduling, data, and initialization requirements are discussed in this section.

- 4.5 Entry
- 4.6 Terminal Area Energy Management (TAEM)
- 4.7 Approach and Landing (A/L)
- 4.8 Return to Launch Site (RTLS) TAEM Guidance
- 4.9 Return to Launch Site Approach and Landing Guidance

Sections 4.5 through 4.9 define the guidance detailed functional requirements for entry through landing. The detailed requirements for each software function and subfunction are described in five subheadings:

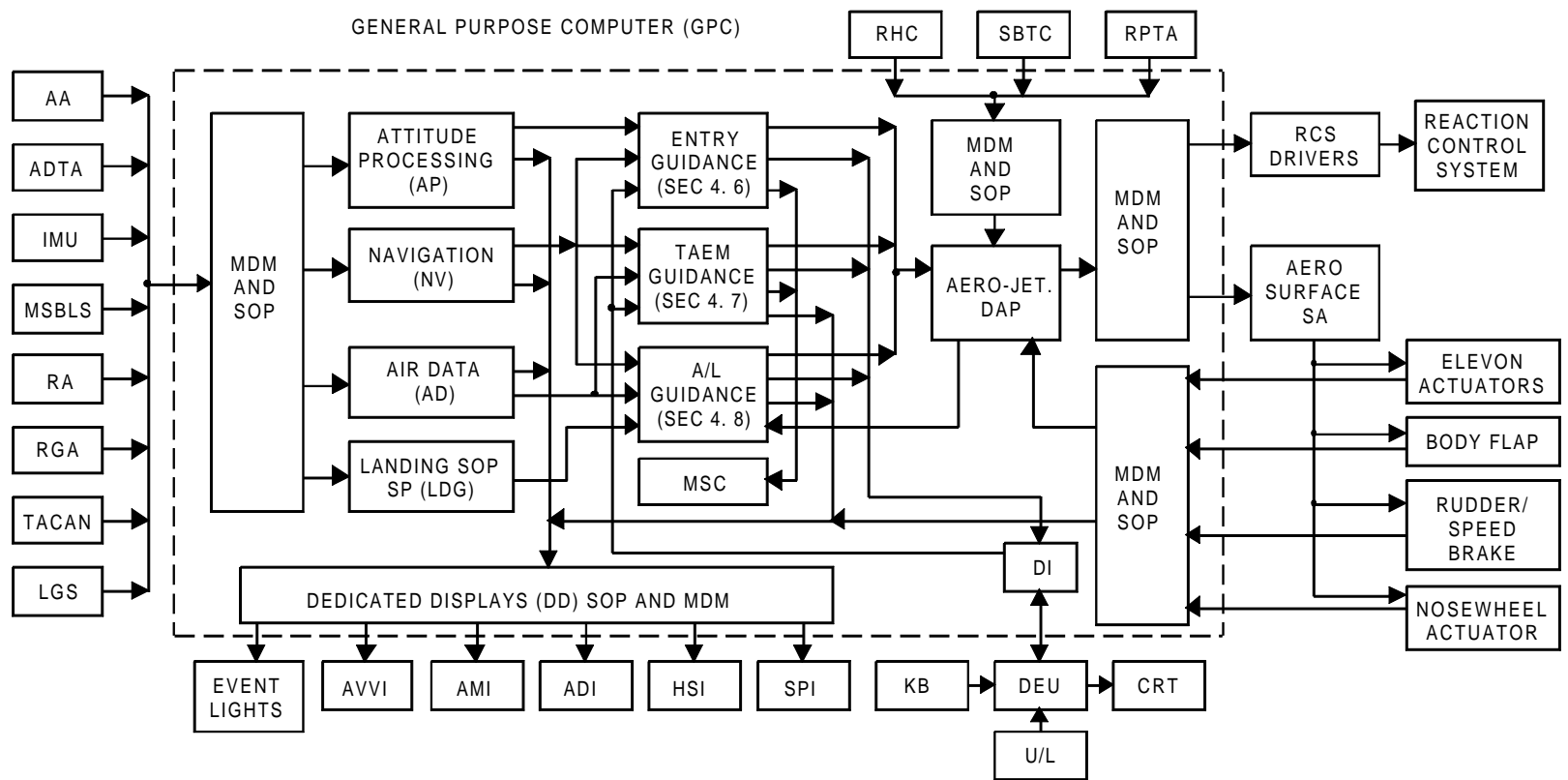
- A. Detailed Requirements. This defines the equations and logic to be executed.
- B. Interface Requirements. These consist of tables of input and output variables and I-loads/constants used in the computations.
- C. Processing Requirements. The execution rate and execution sequence relative to other software functions are described here.
- D. Initialization Requirements. Any flags or variables that must be initialized prior to the first execution of the function are specified. These requirements are only applicable to those parameters which are not explicitly initialized as part of the detailed requirements specifications.
- E. Supplemental Information. Any additional information that aids in understanding the function.

Complete lists of all variables and named constants are listed in Section 5.

The equations of Sections 4.5, 4.6, 4.7, and 4.8 utilize the “CALL” statement frequently. For programming purposes, CALL statements should be interpreted as perform the indicated function. No requirements for double precision have been identified.

Note: In the event of a conflict between the standard principal function tables and the internal tables in Section 4, the principal function tables shall take precedence.

If there is a conflict between the data in the flow diagrams and the written requirements, the written requirements shall have precedence.



SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
AA	ACCELEROMETER ASSEMBLY	KB	KEYBOARD
ADI	ATTITUDE DIRECTION INDICATOR	LGS	LANDING GEAR SWITCHES
ADTA	AIR DATA TRANSDUCER	MSBLS	MICROWAVE SCAN BEAM LANDING SYSTEM
AMI	ALPHA-MACH INDICATOR	RA	RADAR ALTIMETER
AVVI	ALTITUDE - VERTICAL VELOCITY INDICATOR	RGA	RATE GYRO ASSEMBLY
CRT	CATHODE RAY TUBE	RHC	TWO-AXIS ROTATIONAL HAND CONTROLLER
DEU	DISPLAY ELECTRONICS UNIT	RPTA	RUDDER PEDAL TRANSDUCER ASSEMBLY
DI	DISPLAY INTERFACE	SA	SERVO AMPLIFIERS
MSC	MODING, SEQUENCE, AND CONTROL	SBTC	SPEED BRAKE THRUST CONTROLLER
HSI	HORIZONTAL SITUATION INDICATOR	SPI	SURFACE POSITION INDICATOR
IMU	INERTIAL MEASUREMENT UNIT	TACAN	TACTICAL AIR NAVIGATION
		U/L	UPLINK PROCESSOR

(Note: OPS 3 descent guidance principal function references utilized for illustrative purposes)

FIGURE 4.1-1. Shuttle GN&C System Block Diagram and Guidance Interfaces

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4.2 TRACEABILITY

Table 4.2-1 shows the traceability of the software paragraphs in this FSSR with respect to the corresponding Sections of the Level B CPDS' documentation. In addition, table 4.2-2 shows the traceability of the PASS GN&C principal functions located in this FSSR with respect to the applicable BFS paragraphs in the Level C PRD specifications. These tables are provided for information only.

Table 4.2-1. Guidance Requirements Traceability		
Level B PF Number	Level B PF Name (Acronym)	Level C FSSR Section No.
4.8	Entry Guidance (ENT GUID)	4.5
4.9	TAEM Guidance (TAEM GUID)	4.6
4.10	Approach and Landing Guidance (A/L GUID)	4.7
4.204	GRTLS TAEM Guidance (GRTLS TAEM GUID)	4.8
4.234	GRTLS Approach and Landing Guidance (GRTLS A/L GUID)	4.9

Table 4.2-2. Entry Guidance FSSR/PRD Correlation					
Principal Function	FSSR Paragraph	FSSR Title	BFS PRD	PRD Paragraph	BFS Title
G4.8	4.5.2	Entry Guidance	MG038104	3.2.3.3.10.2	EG-Entry Guidance Program Modules
G4.9	4.6.2	Terminal Area Energy Management Guidance	MG038104	3.2.3.3.10.3	TG-TAEM Guidance Program Modules
G4.10	4.7.2	Approach and Landing Guidance	N/A	N/A	N/A
G4.204	4.8	Glide Return-to-Launch-Site (GRTLS) TAEM Guidance	MG038104	3.2.3.3.10.4	Return To Launch Site (RTLS) TAEM Guidance
G4.234	4.9	Glide Return-to-Launch-Site Approach and Landing Guidance	N/A	N/A	N/A

4.3 PARAMETER TABLES

Interface (input/output parameters) tables for each software function within the entry, TAEM, A/L, GRTLS TAEM, and GRTLS A/L guidance functions are in the subsection describing the function within Sections 4.5, 4.6, 4.7, 4.8, and 4.9. Equivalent input names for the entry, TAEM, A/L, RTLS TAEM, and RTLS A/L guidance functions individually are shown in Tables 4.5.2.1–1, 4.6.2.1–1, 4.7.2.1–1, 4.8.2.1–1 and 4.9.2.1–1 respectively.

Input and output parameter tables contain the following information:

MML Number: The master measurement list number used to identify signals that cross major software function boundaries (e.g., from NV to GD).

Name or Symbol: The HAL name used for the variable in the detailed formulation equations and flow charts. For the input tables, both the internal HAL name and the source HAL name are given.

Description: A brief definition of the variable is given.

Source or Destination: The major software function(s) (e.g., NV or FC) that are the variable source or destination is (are) given.

The entry–through–landing guidance input and output tables show a Level B principal function reference for an input source or output destination. Although the Level B nomenclature will be used for the overall input/ output tables for each of the guidance principal functions, an abbreviated nomenclature will be used for the input/output tables used for all subfunctions contained in each of the guidance principal functions.

Units: The physical units of the variable are specified. If the variable is nondimensional, it is denoted by ND. All variables in guidance are in English units; angles may be defined in either degrees or radians.

I–load/constants tables for each software function or subfunction are included in the subsection describing the function. The tables show the MSID number, the HAL name, description, value, units, and class. All parameters are classified as either X (fixed), D or SX (subject to change with software development and testing), K (K–load) or M or MX (mission/weight dependent).

Intermediate variables are not listed in the individual software function subsections. However, complete lists of all parameters (variables and constants) used in the entry, TAEM, and A/L–rollout guidance functions are given in Section 5.1. Also, a description or definition of each parameter is given.

Parameter initialization requirements are defined for each software function and subfunction, and initialization tables are included in the applicable subsection when required.

4.4 GUIDANCE EXECUTION

This section discusses scheduling, input data, and initialization requirements for guidance.

4.4.1 Scheduling

The entry, TAEM, or A/L guidance function is executed when the vehicle is in the appropriate major mode. The guidance execution frequency is also major mode dependent. Major mode guidance functions and execution rates are summarized in Table 4.4.1-1. Guidance scheduling and calling are performed by moding, sequence, and control (MSC).

Major Mode	Guidance Function	Execution Rate (Hz)	Guidance Interval (sec)
304	Entry	0.52	1.92
305	TAEM	1.04	0.96
305	A/L	6.25	0.16
602, 603	GRTLS TAEM	1.04	0.96
603	GRTLS A/L	6.25	0.16

4.4.2 Targeting Data

Navigation supplies targeting data to entry guidance. The targeting data consist of range to the runway threshold and heading error. Range is computed as a great circle (RTAN) to the tangency point with the selected heading alignment cone (HAC) plus the turn around the HAC and the distance to the runway threshold. Heading error is the angle between the velocity heading and the bearing to the HAC tangency point.

4.4.3 Initialization

The initialization requirements for entry guidance are to set the first pass flag START to zero before the first-pass into entry guidance. For TAEM guidance and GRTLS TAEM guidance, the first-pass flag INIT_PASS must be set to 'ON' before the first TAEM or GRTLS TAEM guidance pass. First-pass requirements for each TAEM or GRTLS TAEM subphase are handled by internal flags.

In entry, TAEM and GRTLS TAEM guidance, other variables are initialized on the first-pass by a special initialization software function (EGINIT in entry, TGINIT in TAEM, GRINIT in GRTLS TAEM). The first-pass flags START and INIT_PASS are reset to the non-first-pass value after all initialization computations are completed.

In A/L and GRTLS A/L guidance, the first-pass only equations within each software function are given in the detailed formulation of the function, and all initialized variables are listed in initialization requirements tables for each function. (First-pass may refer to the first A/L guidance pass or to the first pass through the software function.)

4.4.3.1 Reinitialization.

Only during TAEM or GRTLS TAEM can a guidance reinitialization be effected by NV resetting RW_ID. No requirements for a guidance restart have been identified.

4.4.4 Air Data

Air data-related parameters (i.e., dynamic pressure, true airspeed, etc.) are provided by the ADTA SOP based on three RM and operationally dependent sources: (1) probe measurement data, (2) navigationally derived data, and (3) air data default schedules. Guidance operations that may be dependent on source selection currently are only identified for TAEM and GRTLS TAEM, while entry and A/L guidance functional requirements are transparent to air data source selection.

4.5 ENTRY (MAJOR MODE 304)

4.5.1 Requirements Overview

Nominally, this descent major mode (MM304) has typically been initiated at approximately five minutes prior to achieving the “entry interface” altitude of 400,000 feet. It encompasses the bulk of atmospheric reentry trajectory operations and is terminated upon transition to major mode 305 at the supersonic, entry-TAEM, major mode interface. The fundamental guidance requirement during entry is to reach the TAEM interface (defined by a nominal velocity and altitude) within specified limits on range from the selected TAEM heading alignment cone (HAC) and a velocity heading within a few degrees of tangency with the HAC.

In order to achieve the desired entry – TAEM target interface, the entry guidance principal function as described in section 4.5.2 must allow for ranging capabilities in terms of not only downrange but crossrange as well. Since entry like all other atmospheric descent phases is an unpowered flight mode, the only means available for satisfying this ranging capability is through the vehicle’s aerodynamic qualities. Entry aerodynamics also pose the obvious problem for vehicle reusability, namely, entry aero-thermal heating. Flight control attitude stability and control requirements/capabilities as well as vehicle load limits impose additional constraints on how the entry trajectory may be flown.

These entry requirements relative to ranging, reentry heating, vehicle loads, and FCS attitude control have resulted in very restrictive, operationally allowed, angle-of-attack (vs. Mach number) profiles for nominal end-of-mission and intact abort scenarios. These same constraints in conjunction with structural limitations also limit or bound the drag (i.e., dynamic pressure) profile options with respect to nominal descent operations to enable vehicle subsystem certification. Given the imposed restrictions on the angle-of-attack profile and its resultant, correlative, vehicle aerodynamic, L/D characteristics, the only realizable attitude command then available to accomplish drag and ranging control is the vehicle’s bank angle. Rather than enable vertical lift modulation via conventional aircraft pitch axis commands, roll axis commands are used to provide the desired altitude acceleration capability through “rotation” of the aerodynamic lift vector about the velocity vector.

This “rotation” of the lift vector about the velocity vector will then allow for control of the vehicle’s sink rate which in turn is the significant contributory factor governing the drag profile. As the vehicle “falls” or “slices” into the atmosphere, the atmospheric density will naturally increase which will effectuate higher drag accelerations. This phenomenon will continue until the relative velocity reduction provided by the vehicle’s aerodynamic drag is sufficient to offset the effect of increasing density. The rate of change for the resultant drag can then be controlled by managing the altitude rate. Once again, the vertical component of L/D as dependent on the magnitude of the bank angle will govern or control the rate of change of the vehicle’s sink rate.

A modification to entry guidance prior to the Operational Flight Test (OFT) phase involved allowing for a limited degree of pitch axis (i.e., angle-of-attack) command flexibility. This modification referred to as alpha modulation allows the guidance to somewhat divert from the scheduled alpha profile and may be invoked to facilitate convergence of the actual vs. reference drag profiles. Since drag is directly related to the vehicle’s coefficient of drag, C_d , which for any given Mach number is primarily dependent on alpha, the ability to modify the pitch axis command if only by a few degrees will, nonetheless, effectively provide a nearly immediate change to the sensed vehicle drag. This ability to adjust the alpha command profile, albeit minimally, not only expands the guidance ranging footprint capability, but it also helps to “dampen” the effects of “transient” conditions (i.e., roll reversals, phase changes, etc.) on the vehicle’s drag profile.

If the roll axis is then to be the primary downrange control mechanism by enabling vertical L/D commands via “rotation” of the lift vector, crossrange steering can no longer be performed in the conventional manner of issuing a roll axis command which is solely based on nulling out vehicle velocity heading errors. Therefore, cross range steering must be implicitly accomplished via the sign of the roll command. A roll command magnitude of > 0 and < 180 degrees may then be necessarily imposed to initiate and/or sustain desired azimuth or heading changes.

To achieve the required cross range steering objectives, an entry heading error “corridor” is established. The sign of the roll command allows the vehicle to traverse this corridor with the rate of change dependent of the magnitude of the roll command. A maximum heading rate of change will occur when the vehicle’s lift vector is oriented perpendicular to the plane defined by the vertical and down range components of the relative velocity vector (i.e., bank angle = ± 90 degrees). A minimum “rotation” of the lift vector from the local vertical may again be required to ensure that a desired azimuth or heading rate will occur. Once the vehicle obtains the obverse “side” of the defined, entry guidance, heading error corridor, the sign of the roll command will be changed (i.e., + to - or - to +) via a roll reversal to redirect the vehicle back towards the opposite “side” of this heading error corridor.

For contingency entry scenarios, additional flexibility has been allowed with respect to primarily the angle-of-attack profile to promote survivability rather than vehicle reusability through enhanced ranging capabilities. Since the entry angle-of-attack profile, aerodynamically speaking, is on the so-called “back side” of the lift/drag curve (i.e., increasing the angle-of-attack results in a reduction in the vehicle’s L/D and vice versa), the capability to operate at lower alphas will cause the vehicle to exhibit improved lift/drag characteristics. The induced entry performance improvements incurred by operating at reduced angles-of-attack will consequently promote an enhanced, downrange, “stretch” capability. This alteration in the alpha profile, though, will result in a degraded, vehicle re-entry, thermal heating, “resistance” capability. The entry guidance, low-energy, contingency “stretch” mode allows for a crew initiated, automatic reconfiguration of the alpha command profile (as well as other dependencies) in order to maximize the vehicle’s ranging capacity while attempting to adhere to thermal protection system and structural “survivability” limitations.

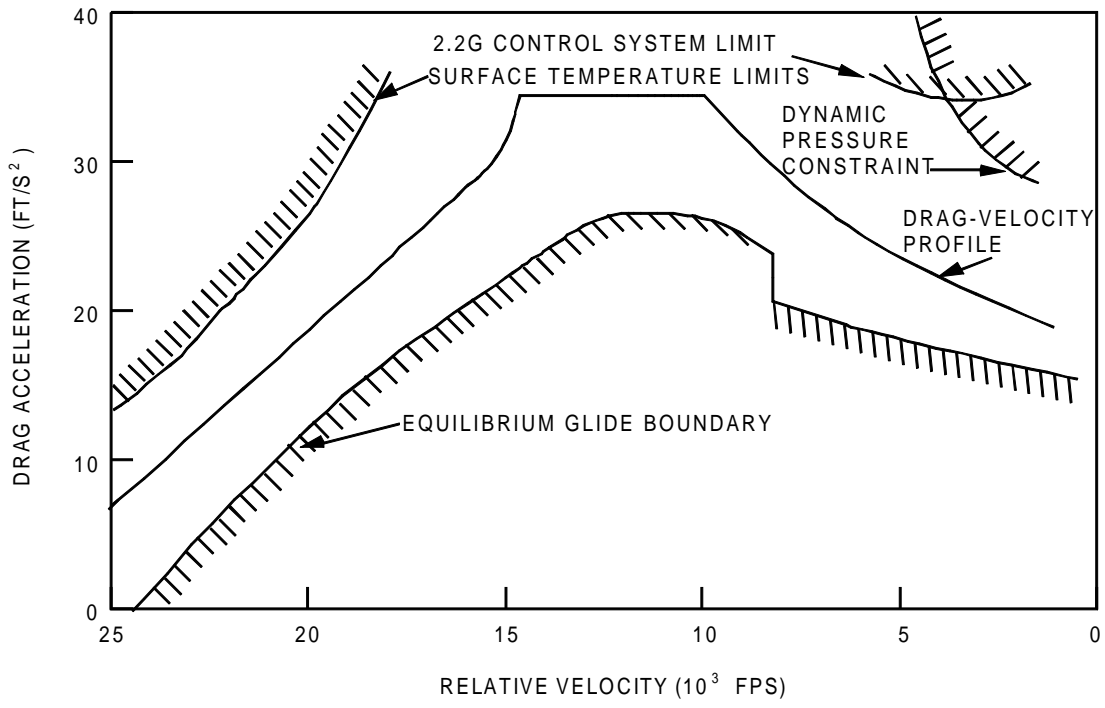
Entry ranging is controlled by drag modulation, based on the predicted range for a selected drag-deceleration versus velocity profile. The drag-velocity profile is chosen to conform with several limits as shown in Figure 4.5.1-1.

Range predictions are based on solutions of the equations of motion for drag profiles that are constant, linear, or quadratic functions of velocity. The desired drag-velocity profile is preselected by means of a mission-dependent data load. This drag-velocity profile is then adjusted as required during closed loop operations to null any range error.

Entry guidance consists of five major phases and begins with an open-loop, pre-entry phase which is maintained until attainment of a sensed total load factor of approximately 0.12g (ref: ASTART test in EGEXEC). Closed-loop ranging is then accomplished through four ranging phases: temperature control, equilibrium glide, constant drag, and transition. The temperature control phase is designed to control the entry trajectory through pullout to a temperature profile consistent with the desired total entry profile shape and the required ranging solution. The temperature control phase consists of two quadratic drag-velocity segments that are selected to minimize surface temperatures and maintain adequate dispersion margins. Temperature control phase dependent range predictions are then derived from these two quadratic segments. The equilibrium glide phase produces an equilibrium glide trajectory consistent with the ranging solution and employs functional dependencies common to the temperature control phase. Once the trajectory intersects the constant drag trajectory required to reach the target, control is transferred to the

constant drag phase. Range predictions are then based on a constant drag profile until the transition phase is entered. The transition phase utilizes a linear drag profile based on the total vehicle's kinetic and potential energy (over mass) to achieve the desired entry-TAEM target interface. Guidance operations will then be transferred to the TAEM guidance principal function upon satisfaction of the MM304 to MM305 transition criteria.

The entry guidance generates roll angle and angle-of-attack commands for use by the flight control system. The speed brake schedule is a flight control dependent profile which is functionally independent of entry guidance.



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 4.5.1-1. Entry Guidance Drag-Velocity Profile and Limits

4.5.2 Entry Guidance (G4.8)

The particulars of the entry guidance principal function are defined in the following paragraphs. Maximum flexibility has been built into the guidance to ensure successful operation over a wide range of initial conditions and potential dispersions.

4.5.2.1 Software Requirements Summary.

The following subsections (4.5.2.2 through 4.5.2.14) define the detailed software requirements for the functions of entry guidance. Each function is described in five subheadings:

- A. Detailed Requirements. The equations and logic performed by the function.
- B. Interface Requirements. Input/output variables and I-loads/constants for each defined functional element within entry guidance are shown in each subsection describing the function. Table 4.5.2.1-1, "Entry Guidance Input / Internal Name Equivalence", provides the correlation between external input data designations and the naming conventions used throughout the following entry guidance detailed requirements subsections.
- C. Processing Requirements. Processing frequency, guidance phase limits, position in function execution sequence, etc.
- D. Initialization Requirements. Any flags or variables that must be given an initial value prior to first execution of the function.
- E. Supplemental Information. Any additional information pertinent to understanding the function.

The functional elements of entry guidance are:

1. An entry guidance executive function, EGEXEC, which calls the other functions in proper sequence depending on the guidance phase and performs the transition logic for progressing from one guidance phase to another.
2. An entry guidance altitude scale height function, EGSCALEHT, which computes an approximate atmospheric density scale height as a function of relative velocity.
3. An entry guidance initialization function, EGINIT, which initializes required variables and computes several auxiliary constants on the first guidance pass.
4. An entry guidance common computation function, EGCOMN, which computes variables commonly used throughout the rest of the guidance.
5. An entry guidance pre-entry phase function, EGPEP, which commands an open-loop bank angle magnitude by computing the associated vertical L/D ratio during the pre-entry phase (Phase 1).
6. An entry guidance range prediction function, EGRP, which predicts the range-to-go for the specified drag-velocity profile during the temperature control and equilibrium glide phases (Phases 2 and 3) and updates the drag-velocity profile to null any error between the actual vs. predicted range.

7. An entry guidance reference parameters function, EGREF, which follows EGRP during Phases 2 and 3. This function establishes reference values of altitude rate and drag acceleration.
8. An entry guidance constant drag phase function, EGREF4, which provides the reference values of drag acceleration and altitude rate during the constant drag phase (Phase 4).
9. An entry guidance transition phase function, EGTRAN, which furnishes the reference drag acceleration and altitude rate during the transition phase (Phase 5).
10. An entry guidance angle-of-attack command function, EGALPCMD, which establishes the angle-of-attack command reference as a function of relative velocity. Prior to the onset of alpha modulation, the angle-of-attack command reference will be used by EGALPCMD to generate the angle-of-attack command issued to the aerojet DAP and display functions. Following initiation of alpha modulation, the EGROLCMD function will provide the entry guidance angle-of-attack command output.
11. An entry guidance gain select function, EGGNSLCT, which computes phugoid damping coefficients (i.e., closed-loop controller gains) used in computing the vertical L/D command.
12. An entry guidance lateral logic and vertical L/D command function, EGLODVCMD, which derives the closed-loop L/D reference(s), vertical L/D command(s), the desired roll direction, and the \dot{h} feedback correction term.
13. An entry guidance roll command function, EGROLCMD, which computes the roll angle command, the unlimited roll command, and the roll command reference. This function also provides the output angle-of-attack command once alpha modulation has been initiated.
14. Additionally, a guidance auto FCS PTI acceptance flag, GUID_ACCEP, is set per altitude acceleration and roll reversal-related dependent constraints (refer to EGCOMN and EGLODVCMD functions).

Table 4.5.2.1-1. Entry Guidance Input/Internal Name Equivalence				
MSID	Source Input Name	Guidance Internal Name	Description	Source
V95L0150C	V_MAG	VI	Vehicle inertial speed	ENT UPP
V95L0151CC	REL_VEL_MAG	VE	Ground rel vel magnitude	ENT UPP
V95A0160CB	ACC_DRAG	DRAG	Drag decel	ENT UPP
V95U0163CA	LOAD_TOTAL	XLFAC	Total load factor	ENT UPP
V95H0165CB	ALT_WHEELS	HLS	Alt to Nav base	ENT UPP
V95L0265CD	H_DOT_ELLIPSOID	RDOT	Estimated altitude rate	ENT UPP
V95H0172C	DELAZ	DELAZ	Heading error wrt HAC	ENT UPP
V95H0176CA	RNG_TO_RW_THRESH	TRANGE	Range to RW threshold via WP1	ENT UPP
V95U0180C	LOD	LOD	Lift/drag	ENT UPP
V90H2202C	PHI	ROLL	Body roll attitude euler angle	A/E ATT PROC
V95H3021C	ALPHA	ALPHA	GN&C angle of attack	ADTA SOP
V93X5201XA	DLRDTZ	DLRDTZ	Zero H dot bias cmd	ENT TRAJ 1
V93X5201XB	DLRDTZ	DLRDTZ	Zero H dot bias cmd	ENT TRAJ 2
V93X5201XC	DLRDTZ	DLRDTZ	Zero H dot bias cmd	ENT TRAJ 3
V93X5201XD	DLRDTZ	DLRDTZ	Zero H dot bias cmd	ENT TRAJ 4
V93X5201XE	DLRDTZ	DLRDTZ	Zero H dot bias cmd	ENT TRAJ 5
V95A0170CB	ACC_VERT	VERTAC	Vertical accel in topodetic coord	ENT UPP
V90X1642XA	AUTORY_LAMP	AUTORY_LAMP	Roll/yaw auto flag	Aerojet DAP
V93X0080XA	ILEFLG	ILEFLG	Low-energy item entry	ENT TRAJ 1
V93X0080XB	ILEFLG	ILEFLG	Low-energy item entry	ENT TRAJ 2
V93X0080XC	ILEFLG	ILEFLG	Low-energy item entry	ENT TRAJ 3
V93X0080XD	ILEFLG	ILEFLG	Low-energy item entry	ENT TRAJ 4
V93X0080XE	ILEFLG	ILEFLG	Low-energy item entry	ENT TRAJ 5
V90X8658X	TAL_ABORT_DECLARED	ITAL	TAL abort discrete	MSC

4.5.2.2 Entry Guidance Executive (EGEXEC).

The EGEXEC function calls the other entry guidance functions in proper sequence and controls guidance phase transitions.

A. Detailed Requirements. Entry guidance is divided into five phases: pre-entry, temperature control, equilibrium glide, constant drag, and transition. Each phase, except pre-entry, computes a reference drag acceleration profile that is based upon the ranging requirement and the vehicle constraints. Figure 4.5.1-1 illustrates a representative reference drag profile along with system or design limits.

The transition to the entry major mode is initiated by crew action, and entry guidance is activated upon transition to the entry major mode.

The computations performed during each guidance cycle vary with the guidance phase. The active guidance phase is defined by the integer variable ISLECT according to the table below:

<u>ISLECT</u>	<u>Guidance Phase</u>
1	Pre-entry
2	Temperature control
3	Equilibrium glide
4	Constant drag
5	Transition

The entry guidance phase transition logic is summarized in Table 4.5.2.2-1.

The pre-entry phase commands a preselected roll angle in the EGPEP function. The pre-entry phase (ISLECT = 1) can be terminated by any of three conditions:

1. Normal termination: The pre-entry phase is normally terminated by setting the ISLECT flag to 2 when the total vehicle acceleration (load factor) exceeds the threshold value of ASTART (V97U0042C) ft/s^2 .
2. Alternate terminations: If, at the threshold load factor level (ASTART), the current constant drag level to reach the target is greater than the desired constant drag level (i.e., $T2 > \text{ALFM}$ [V97U0009C]), ISLECT is set to 4. This could occur for an extremely short range case. Or, at the threshold load factor level, if the current relative velocity is less than VTRAN (V97U0441C), ISLECT is set to 5.

The temperature control phase (ISLECT = 2) computes the required drag velocity profile during the high-temperature region of entry. The EGRP and EGREF functions contain the detailed temperature control equations used by the entry guidance. During the temperature control phase, the drag-velocity reference trajectory is divided into two quadratic segments. The EGREF function determines which of these quadratics is to be used. Figure 4.5.2.2-1 presents example quadratics for this phase. The quadratic for the higher velocity region is used when the vehicle's relative velocity is greater than the quadratic boundary velocity, VA1 (I-load), and the calculated reference drag test value, DRF, is greater than zero as computed in EGREF. If either test is failed, then the reference parameters RDTREF and DREFP computed for the lower velocity drag profile are used. The quadratic segment switching point is controlled by the mission load parameter GS1. The EGREF quadratic switching logic is similar to that used for guidance phase transitions.

The temperature control phase can be terminated in four ways:

1. Normal termination: The temperature control phase normally transfers to the equilibrium glide phase, ISLECT = 3. Transfer is planned to occur when the drag reference profiles for the temperature control phase and the equilibrium glide phase intersect as illustrated in Figure 4.5.2.2-2. However, if the slopes of the two intersecting profiles are different, the roll-angle command may be discontinuous at the transfer point. Roll-smoothing logic provides a smooth roll-angle command history for minimum RCS fuel usage by transferring phases when the commanded roll angle is effectively the same for both phases. This transition occurs before the intersection point of the drag profiles and is accomplished by use of the following equation:

$$\text{If } VE < VA \text{ and } DREFP < DREFP3, \text{ then ISLECT} = 3.$$

where $DREFP3 (= DREFP1 + GS2 (RDTREF - RDTRF1))$ is computed in the EGREF function. The value of GS2 determines the transfer point.

2. Alternate termination: The guidance transfers to Phase 3 when $VE < VB1$ if the roll-smoothing logic has not been satisfied by that time. Thus, if $VE < VB1$, then ISLECT = 3.
3. Alternate termination for short ranges: For very short range targets, the desired constant drag level may be reached before equilibrium glide phase initiation. In this case, control is transferred directly from the temperature control phase to the constant drag phase (ISLECT = 4) when

$$VE < VCG + DELV$$

and

$$DREFP > DREFP4$$

where $DREFP4 (= T2 + GS3 (RDTREF + 2. HS T2/VE))$ is computed in EGREF. Roll command smoothing is provided via GS3.

4. Extremely short range termination: Transition to the constant drag phase (ISLECT = 4) also occurs if

$$T2 > ALFM$$

where T2 is computed in EGCOMN.

The equilibrium glide phase (ISLECT = 3) shapes the drag velocity profile so that the constant drag level to reach the target converges on the desired constant drag level, ALFM. The functions EGRP and EGREF contain the equilibrium glide equations. There are three possible transfers from the equilibrium glide phase:

1. Normal termination: The equilibrium glide phase will transition to the constant drag phase, ISLECT = 4. Roll-smoothing logic is provided via GS3. Transfer occurs when

$$VE < VCG + DELV$$

and

$$DREFP > DREFP4$$

where DREFP4 is computed in EGREF.

2. Alternate termination: For very long range trajectories, the predicted velocity at the intersection of the equilibrium glide and constant drag phases is less than the transition phase initiation velocity, VTRAN. When this occurs, the equilibrium glide phase transfers directly into the transition phase (ISLECT = 5). The ISLECT = 3 to ISLECT = 5 transition occurs when

$$VE < VTRAN + DELV$$

and

$$VCG < VTRAN$$

and

$$DREFP > DREFP5$$

where DREFP5 is computed in EGCOMN. As in other phases, roll-smoothing logic is provided by the mission load constant GS4.

3. Alternate termination: For extremely short ranges, as in the temperature control phase, transition to the constant drag phase (ISLECT = 4) occurs if

$$T2 > ALFM$$

where T2 is again computed in EGCOMN.

The constant drag phase (ISLECT = 4) shapes the entry profile along a constant drag velocity profile to maximize control system margins. The EGREF4 function contains the constant drag range prediction and controller equations. The constant drag phase terminates and transfers to the transition phase (ISLECT = 5) when

$$VE < VTRAN + DELV$$

and

$$DREFP > DREFP5$$

where DREFP5 is computed in EGCOMN.

The transition phase is the final entry phase and is used to guide the orbiter to the proper TAEM interface conditions. Entry guidance is terminated upon transition to the TAEM major mode. The entry-to-TAEM transition logic is defined by

If $VE < V_TAEM$, then $EG_END = TRUE$.

In low-energy contingency abort situations, special low-energy logic may be exercised. This logic is manually enabled by the low-energy item entry (ILEFLG). The logic consists of two parts:

1. Phugoid logic – Allows the Orbiter to maximize downranging capability by flying altitude phugoids while following a contingency abort angle-of-attack profile.
2. Roll command logic – Computes a roll command to satisfy crossranging requirements.

When the low energy situation is sufficiently improved, the low-energy logic will automatically disengage and converge to the nominal entry guidance reference drag acceleration and angle-of-attack profiles. The low-energy logic will also disengage whenever the logic is disabled, i.e., ILEFLG is turned off.

To execute the entry guidance computations properly, the following functions must be executed in the sequence specified below:

1. The EGSCALEHT function is called.
2. On the initial entry guidance pass (START = OFF), EGINIT is executed.
3. If the low-energy item entry is not set, the low-energy logic engagement discrete and the low-energy logic first-pass flag are zeroed.

If ILEFLG = OFF, then Equation Set A is executed.

A.1 ICNTAL = OFF

A.2 ILEINT = 0

4. On any entry guidance pass for which the low-energy item entry is set and the low-energy logic first-pass flag is less than one, certain parameters must be initialized.

If ILEFLG = ON and ILEINT < 1, then Equation Set B is executed.

B.1 ICNTAL = ON

B.2 ICNVRG = 0

B.3 NCNVRG = 0

B.4 ALPCA1 = ALPHA

B.5 IALCNV = 0

B.6 DZFCTR = DLZFAC

$$B.7 \text{ DZFDEL} = \text{MAX}[\text{DZFMIN}, (\text{DZFDL1} + \text{DZFDL2 VI})]$$

$$B.8 \text{ ILEINT} = 1$$

5. If the low-energy logic is engaged, then a biased range to the runway threshold is computed, if required.

If ICNTAL = ON, then Equation Set C is executed.

$$C.1 \text{ If } \text{ABS}(\text{DELAZ}) > \text{DZBIAS}, \\ \text{then } \text{RTBIAS} = \text{TRANGE SIN}(\text{ABS}(\text{DELAZ})) \text{ TAN}(\text{ABS}(\text{DELAZ})) \\ \text{else } \text{RTBIAS} = 0.0$$

$$C.2 \text{ TRNGLE} = \text{TRANGE} + \text{RTBFAC RTBIAS}$$

6. The EGCOMN function is called.
7. EGALPCMD is executed.
8. The phase transition logic for the pre-entry phase (ISLECT = 1) and the first alternate termination test for the temperature control phase (if VE < VB1, then ISLECT = 3) are executed within EGEXEC. The tests to transfer to Phase 4 if T2 > ALFM are also made at this time.

Additionally, transfer to the transition phase (ISLECT = 5) from any other guidance phase will occur for low-energy contingency abort situations if the low-energy logic is engaged (ICNTAL = ON) and VE is less than the transition velocity (VTRAN):

If ICNTAL = ON and VE < VTRAN, then ISLECT = 5

9. Phase dependent functional dependencies as well as the remainder of the entry guidance phase transition logic are now executed dependent on the value of ISLECT (i.e., DO CASE ISLECT).

ISLECT = 1: perform EGPEP

ISLECT = 2 or 3: perform EGRP;
perform EGREF;

If VE < VCG + DELV and DREFP > DREFP4,
then ISLECT = 4;

If ISLECT = 2,
then if VE < VA and DREFP < DREFP3, then ISLECT = 3;

else if VE < VTRAN + DELV and VCG < VTRAN
and DREFP > DREFP5, then ISLECT = 5

ISLECT = 4: perform EGREF4;

If $VE < VTRAN + DELV$ and $DREFP > DREFP5$,
then $ISLECT = 5$

$ISLECT = 5$: perform EGTRAN

10. Completion of the attitude command update process will now be accomplished by executing EGGNSLCT, EGLODVCMD, and EGROLCMD. Note: if $ISLECT = 1$, then EGGNSLCT and EGLODVCMD are bypassed and only EGROLCMD is processed.
11. The entry guidance termination test (i.e., $VE < V_TAEM$) is then performed.

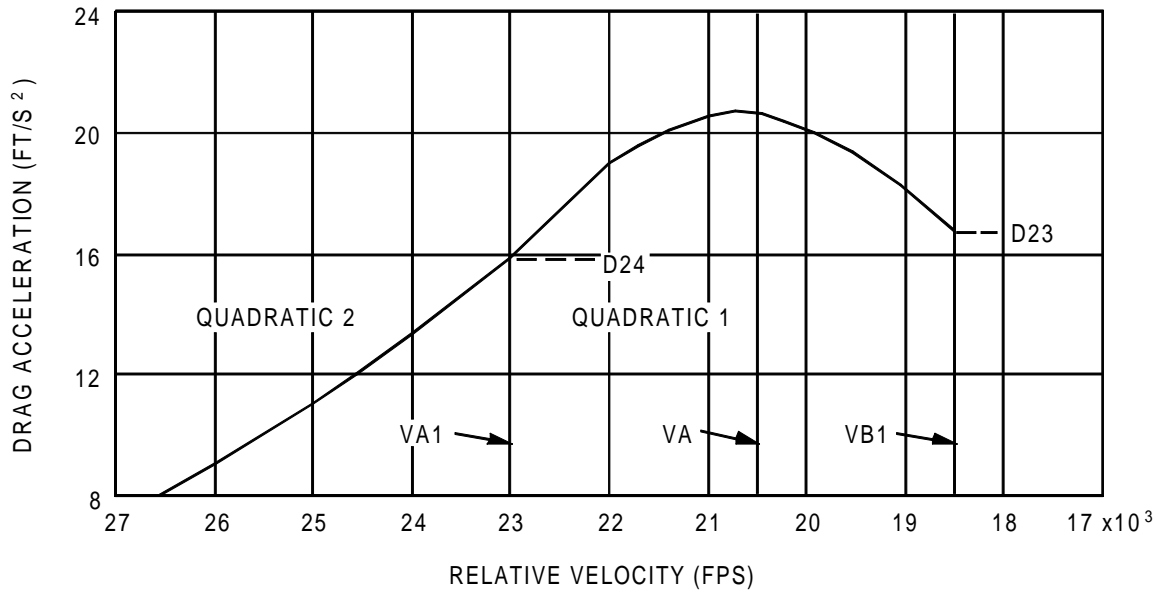
B. Interface Requirements. The input and output parameters of EGEXEC are listed in Table 4.5.2.2–2. The I–loads/constants used in EGEXEC are listed in Table 4.5.2.2–3.

C. Processing Requirements. The EGEXEC function is processed at the entry guidance rate (0.52 Hz) during the entire entry major mode.

D. Initialization Requirements. The initialization flag, START, must be set to “OFF” before the first entry into EGEXEC.

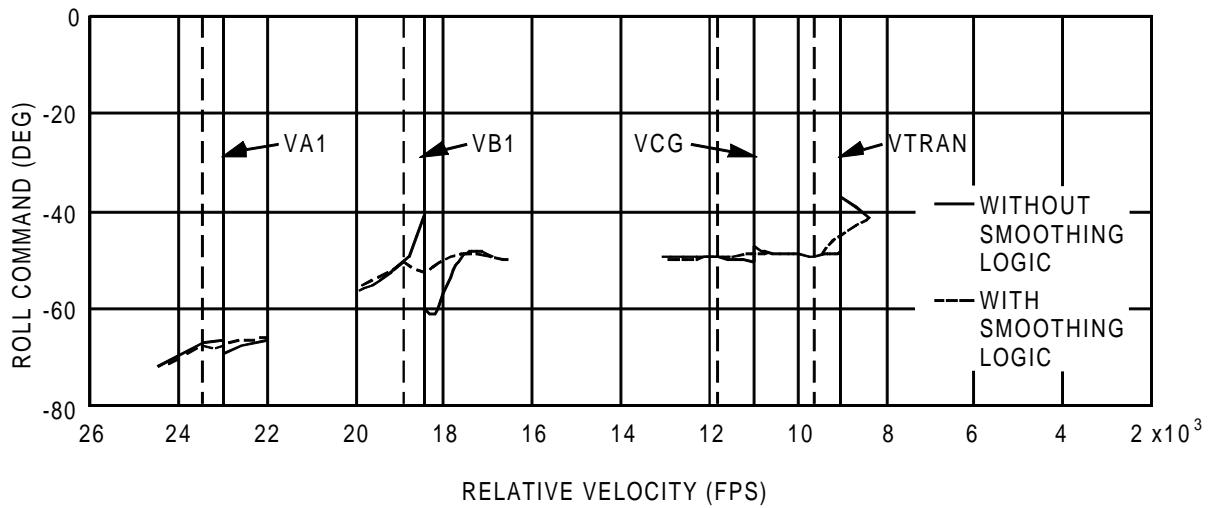
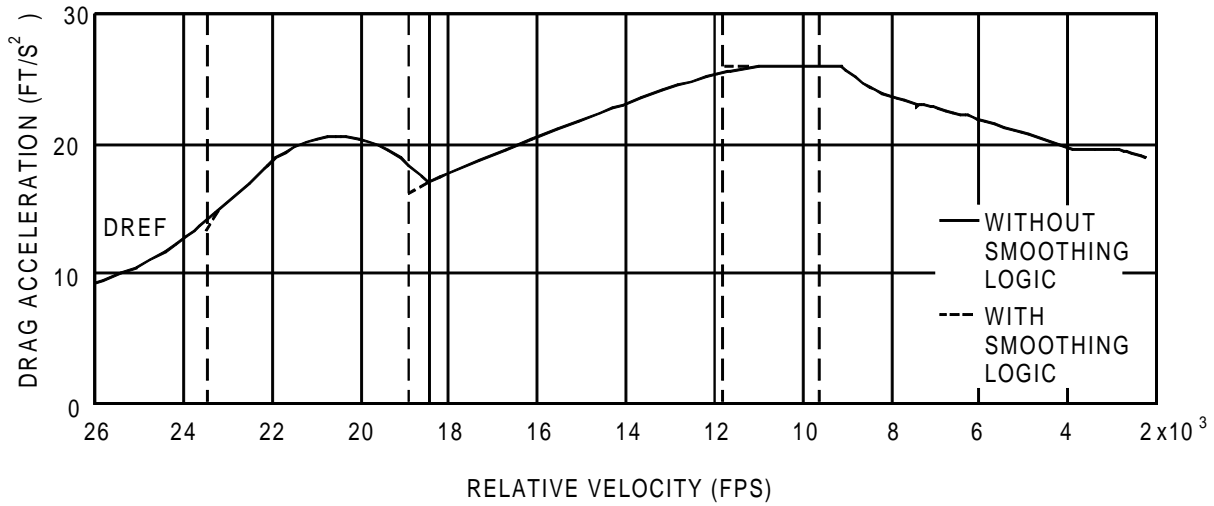
E. Supplemental Information. The detailed requirements for EGEXEC do not explicitly denote "protection" for DELAZ magnitudes which equal or exceed $\pi/2$ radians (90 degrees) for the low-energy logic, RTBIAS calculation which invokes use of the tangent function. Heading error magnitudes which equal or exceed $\pi/2$ are currently beyond the operational applicability for the low-energy logic; therefore it is acceptable for the protection logic to set RTBIAS to zero instead of a number of very large magnitude. None-the-less, functional protection against a DELAZ value of $\pm\pi/2$ is warranted by the implementor to eliminate a potential DR condition.

Entry guidance, functional dependencies will invoke a low–energy logic engaged test (ICNTAL) for determination of which range–to–go should be utilized (TRANGE vs. TRNGLE) in the calculation of required reference parameters. Per current requirements, TRNGLE could be set equal to TRANGE prior to the EGEXEC, ICNTAL = ON test used to define the biased range to the runway threshold. Subsequent “if” tests as dependent on ICNTAL used to determine which range value to use would then become unnecessary as TRNGLE would reflect the desired biased or unbiased range–to–go value. The FSSR detailed requirements will remain as is to minimize possible confusion with respect to what range value is actually to be used.



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 4.5.2.2-1. Temperature Control Phase Quadratic Definition



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 4.5.2.2-2. Roll-Angle Smoothing Logic Between Guidance Phases

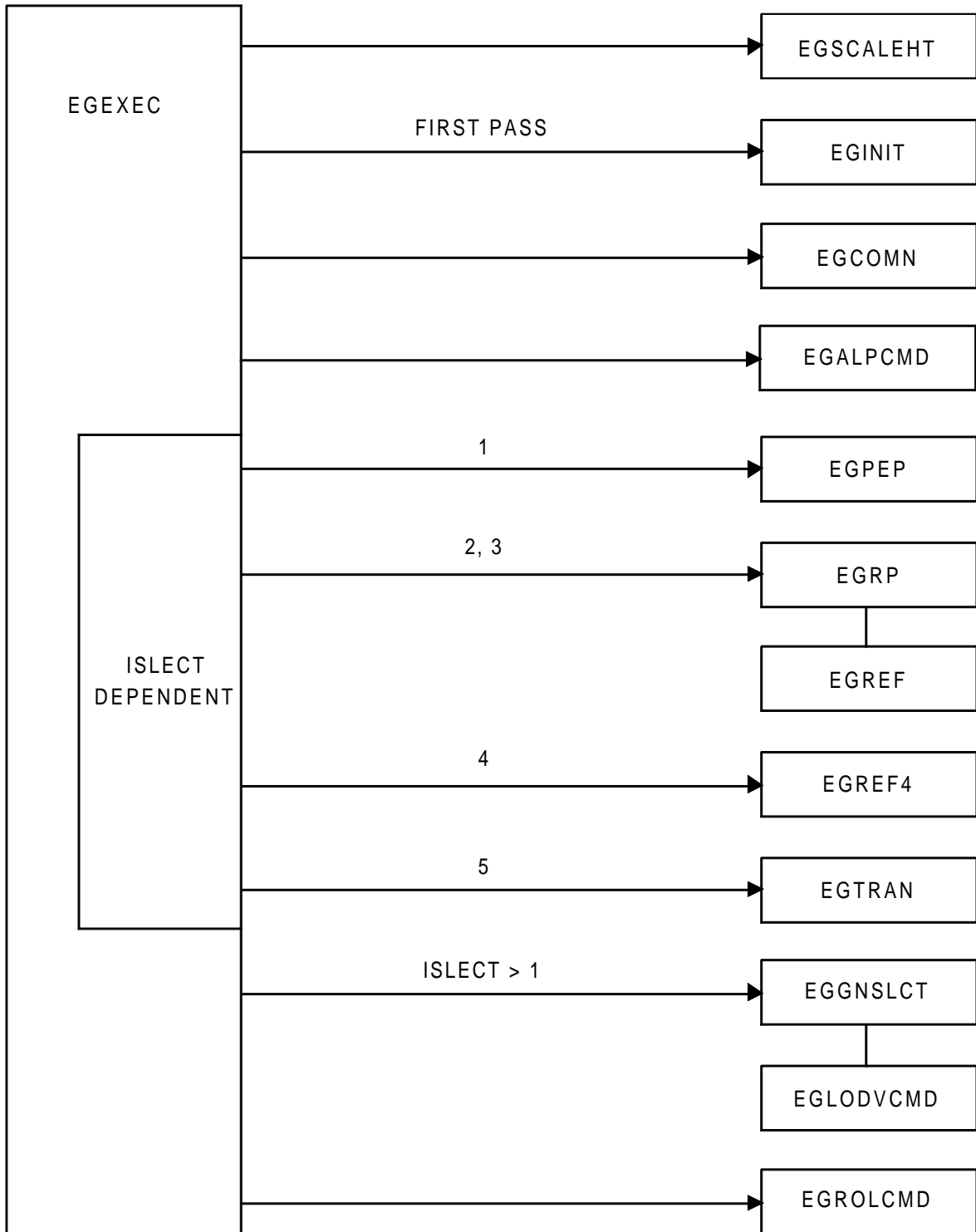


FIGURE 4.5.2.2-3. Entry Guidance Sequence

Table 4.5.2.2-1. Guidance Phase Transition Logic					
Guidance Phase	Pre-Entry	Temperature Control	Equilibrium Glide	Constant Drag	Transition
ISLECT	1	2	3	4	5
Previous possible phase	NA Crew enables the entry major mode (MM304)	Pre-entry	Temperature control	Pre-entry Temperature control Equilibrium glide	Pre-entry Equilibrium glide Constant drag
Possible phase transfer	Temp control Constant drag Transition	Equilibrium glide Constant drag	Constant drag Transition	Transition	NA
Transfer logic	XLFAC > ASTART ISLECT= 2	VE < VA and DREFP < DREFP3	VE < VCG + DELV and DREFP >	VE < VTRAN + DELV and DREFP >	MM305 initiated when VE < V_TAEM
	XLFAC > ASTART and T2 > ALFM ISLECT = 4	ISLECT = 3 VE < VB1 ISLECT = 3	DREFP4 ISLECT = 4 VE < VTRAN + DELV and	DREFP5 ISLECT = 5	
	XLFAC > ASTART and VE < VTRAN ISLECT = 5	VE < VCG + DELV and DREFP > DREFP4	VCG < VTRAN and DREFP > DREFP5 ISLECT = 5		
		ISLECT = 4	T2 > ALFM ISLECT = 4		
		T2 > ALFM ISLECT = 4			
		Temperature control phase internally transfers quadratic D-V segments when VE < VA1 or DRF < 0			

NOTE – Transfer to the transition phase (ISLECT = 5) from any other guidance phase may occur if ICNTAL = ON and VE < VTRAN.

Table 4.5.2.2-2. EGEXEC Input/Output Parameters

Name	Description	Source/Destination	Units	Type
INPUTS				
START	Entry guidance first pass flag	EGINIT	ND	D
XLFAC	Current load factor	NAV	ft/sec ²	F
T2	Constant drag level to reach target	EGCOMN	ft/sec ²	F
VE	Ground relative velocity magnitude	NAV	ft/sec	F
ISLECT	Entry guidance phase counter	EGINIT	ND	I
VCG	Predicted intersection velocity between constant drag and equilibrium glide phases	EGRP	ft/sec	F
DREFP	Drag reference used in controller	EGREF, EGREF4, EGTRAN	ft/sec ²	F
DREFP3	Test value of DREFP for transition to Phase 3	EGREF	ft/sec ²	F
DREFP4	Test value of DREFP for transition to Phase 4	EGREF	ft/sec ²	F
DREFP5	Test value of DREFP for transition to Phase 5	EGCOMN	ft/sec ²	F
ILEFLG	Low-energy item entry	ENT TRAJ 1-5	ND	D
DELAZ	Orbiter heading deviation from tangency with the selected HAC	NAV	rad	F
TRANGE	Range to the runway threshold	NAV	nmi	F
ICNTAL	Low-energy logic engagement discrete	EGROLCMD	ND	D
ILEINT	Low-energy logic first pass flag	EGINIT	ND	I
ALPHA	Angle of attack	ADTA SOP	deg	F
VI	Vehicle inertial speed	NAV	ft/sec	F
OUTPUTS				
ISLECT	Entry guidance phase counter	ENT DIP, TLM, EGLODVCMD, EGCOMN, EGALPCMD, MEDS FC GNC XFER	ND	I
EG_END	Entry guidance termination flag	MSC, TLM	ND	D
ICNTAL	Low-energy logic engagement discrete	ENT TRAJ 1-5, EGCOMN, EGRP, TLM, EGTRAN, EGLODVCMD, EGROLCMD	ND	D
ICNVRG	Low-energy logic: drag profile convergence flag	EGROLCMD	ND	I
NCNVRG	Low-energy logic: drag profile convergence counter	EGROLCMD	ND	I
TRNGLE	Low-energy logic: biased range to the runway threshold	EGCOMN, EGRP, EGTRAN	nmi	F
IALCNV	Low-energy logic: alpha profile convergence flag	EGROLCMD	ND	I
ALPCA1	Low-energy logic: filtered alpha command	EGROLCMD	deg	F
DZFCTR	Low-energy logic: variable DELAZ factor for roll command computation	EGLODVCMD	ND	F
DZFDEL	Low-energy logic: DZFCTR increment / decrement	EGLODVCMD	ND	F
START	Entry guidance first pass flag	EGINIT	ND	D

Table 4.5.2.2-3. EGEXEC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0009C	ALFM	Desired constant drag level		ft/sec ²	MX
V97U0441C	VTRAN	Transition velocity		ft/sec	MX
V97U0430C	VB1	Boundary velocity between temperature control and equilibrium glide phases		ft/sec	MX
V97U0421C	VA	Initial velocity for temperature quadratic $dD/dV = 0$		ft/sec	MX
V97U0042C	ASTART	Sensed acceleration to enter phase 2		ft/sec ²	SX
V97U0420C	V_TAEM	Reference velocity at entry-TAEM interface	2500.0	ft/sec	K
V97U0118C	DELV	Phase transfer velocity bias		ft/sec	SX
V97U9526C	RTBFAC	Low-energy logic: range bias factor		ND	MX
V97U9533C	DZBIAS	Low-energy logic: DELAZ value for range biasing		rad	MX
V97U9532C	DLZFAC	Low-energy logic: DELAZ factor for roll command computations		ND	MX
V97U9510C	DZFMIN	Low-energy logic: minimum value for DZFDEL		ND	MX
V97U9511C	DZFDL1	Low-energy logic: constant for DZFDEL equation		ND	MX
V97U9512C	DZFDL2	Low-energy logic: VI coefficient for DZFDEL equation		sec/ft	MX

4.5.2.3 Altitude Scale Height (EGSCALEHT).

Function EGSCALEHT generates an altitude scale height (of atmospheric density) based on the 1962 standard atmosphere to be used in computing the altitude rate reference parameter.

A. Detailed Requirements. Empirical curve fits of the altitude scale height, HS, as a function of relative velocity have been produced for the 1962 standard atmosphere. The altitude scale height relates the atmospheric density, ρ , to the reference density, ρ_0 , through the approximate relationship

$$\rho = \rho_0 e^{-H/HS},$$

and is used to compute altitude rate reference from the equation:

$$RDTREF = -HS \left(\frac{2D}{V_e} + \frac{\dot{D}}{D} \right)$$

The scale height, HS, is computed from:

If ($VE < VHS1$), then $HS = HS01 + HS11 VE$.

If ($VE \geq VHS1$ and $VE < VHS2$), then $HS = HS02$.

If ($VE \geq VHS2$), then $HS = HS03 + HS13 VE$.

If ($HS < HSMIN$), then $HS = HSMIN$.

Note: Constant or I-load values will be selected so that VHS1 will always be less than VHS2 and the HS function will be continuous across the HS segment selection boundary values of VHS1 and VHS2.

B. Interface Requirements. The input-output parameters for EGSCALEHT are listed in Table 4.5.2.3-1. The I-loads are listed in Table 4.5.2.3-2.

C. Processing Requirements. EGSCALEHT is processed at the normal entry guidance rate and must be executed before EGCOMN, EGREF, EGREF4, EGTRAN, or EGLODVCMD are executed.

D. Initialization Requirements. None.

Table 4.5.2.3-1. EGSCALEHT Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
OUTPUTS				
HS	Atmospheric density scale height	EGCOMN, EGREF, EGREF4, EGTRAN, EGLDVCMD, TLM	ft	F

Table 4.5.2.3-2. EGSCALEHT I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0435C	VHS1	Scale height versus VE segment boundary		ft/sec	SX
V97U0436C	VHS2	Scale height versus VE segment boundary		ft/sec	SX
V97U0294C	HS01	Scale height constant, tabular data		ft	SX
V97U0295C	HS02	Scale height constant, tabular data		ft	SX
V97U0296C	HS03	Scale height constant, tabular data		ft	SX
V97U0297C	HS11	Scale height slope wrt VE, tabular data		sec	SX
V97U0298C	HS13	Scale height slope wrt VE, tabular data		sec	SX
V97U0293C	HSMIN	Minimum value of scale height		ft	SX

4.5.2.4 Entry Guidance Initialization (EGINIT).

Function EGINIT serves as the initialization routine for the entry guidance.

A. Detailed Requirements. EGINIT calculates the necessary initialization parameters for entry guidance when the START flag is set to zero (first guidance pass). The following parameters are initialized:

First pass flag for transition phase	ITRAN = OFF
Mode select flag	ISLECT = 1 (pre-entry phase)
Constant drag level	T2 = 0.
Drag reference	DREFP = 0.
Anchor drag level	D23 = D230
Phase 3/4 boundary	VCG = VQ
Roll direction flag	RK2ROL = -SIGN(DELAZ), (NOTE: RK2ROL has the value ± 1 .)
Lateral deadband flag	IDBCHG = OFF
Previous value of DELAZ	DZOLD = 0.
\dot{h} feedback	DLRDOT = 0.
\dot{h} lockout flag for saturated roll command	LMFLG = 0
\dot{h} feedback zero flag	DLRDTZ = OFF
\dot{h} feedback velocity lockout	VTRB = 60000.
Past value of DD	DDP = 0.
Past value of RK2ROL	RK2RLP = RK2ROL
Initial value of α modulation flag	ICT = 0
Auto PTI DELAZ deadband	DYL = DY1
Initial roll command flag	ROLLC_FLG = OFF
Initial value of roll command	ROLLC(1) = 0.
Auto PTI DELAZ deadband counter	DYLN = 0.

Auto PTI velocity lockout

$$VTRB1 = 60000.$$

The following parameters, which are used in other entry guidance functions and which remain unchanged, are computed in EGINIT to avoid recomputation for each guidance cycle:

$$\begin{aligned} VQ2 &= VQ^2 \\ VSAT2 &= VSAT^2 \\ VSIT2 &= VS1^2 \end{aligned}$$

The nominal transition range is computed as

$$\begin{aligned} RPT &= -((ETRAN - EEF4) \text{ LOG}(DF/ALFM)/(ALFM - DF) \\ &+ (VTRAN^2 - VQ^2)/(2. ALFM)) \text{ NAUTMI_PER_FT} + RPT1 \end{aligned}$$

The following constants used in EGRP are defined:

$$\begin{aligned} DX(1) &= 1. & A(1) &= AK \\ VO(1) &= VB1 & VO(2) &= VA1 \\ VX(1) &= VA & VX(2) &= VA2 \\ VF(1) &= VA1 & A(2) &= AK1 \end{aligned}$$

The variable VB2, which is constant in Phase 2, is initialized as

$$VB2 = VB1^2.$$

The constant component of RCG is computed:

$$RCG1 = \text{NAUTMI_PER_FT} (VSIT2 - VQ2)/(2. ALFM)$$

The low-energy logic maximum velocity for nonzero roll commands is computed, the initial inertial velocity value is set and the upper limit for the pullout alpha is set to protect for large heading errors.

$$\begin{aligned} VTURN &= VTURN1 \text{ VI} + VTURN2 \\ VI_INIT &= VI \\ \text{If } ABS(DELAZ) < DLZ_LM_ALP_HI, & \\ \text{then } ALPHPO_HI &= ALPHPO(2) \\ \text{else } ALPHPO_HI &= ALPHPO(3) \end{aligned}$$

The low-energy logic first-pass flag and pullout flag are also initialized:

$$\begin{aligned} ILEINT &= 0 \\ \text{If } RDOT > 0.0, & \text{ then } IRDOT = 0 \\ \text{else } IRDOT &= 1 \end{aligned}$$

If the transoceanic abort mode is in effect (i.e., ITAL = TRUE), then the following parameters must be initialized or reset with respect to nominal entry values:

$$NALP = NALP1 \qquad VC16 = 0.$$

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VNOALP = 0.

VRDT = 0.

VYLMAX = 0.

ITAL1 = OFF

The segment counter for the multi-segment function ALPCMD is then initialized to ensure that the initial values will allow the segment search logic to function correctly and to minimize the first-pass search time:

IALP = NALP

Finally, the guidance initialization flag, START, is set to "TRUE"; the EGRP first pass initialization flag, RP_START, is set to "OFF"; and EG_END, the entry guidance termination flag, is set to "FALSE".

B. Interface Requirements. The input and output parameters for EGINIT are listed in Table 4.5.2.4-1. The I-loads/constants are listed in Table 4.5.2.4-2.

C. Processing Requirements. EGINIT is processed only on the first guidance pass.

D. Initialization Requirements. EGINIT's *raison d'être*.

E. Supplemental Information. RPT1 (desired range at EEF4 energy level) may be dependent on orbiter weight, landing site, and approach heading.

Table 4.5.2.4-1. EGINIT Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
DELAZ	Velocity heading deviation from tangency with the selected HAC	NAV	rad	F
ITAL	Transoceanic abort discrete	MSC	ND	D
RDOT	Current altitude rate with respect to oblate earth	NAV	ft/sec	F
VI	Vehicle inertial speed	NAV	ft/sec	F
START	Entry guidance first pass flag	EGEXEC	ND	D
OUTPUTS				
ITRAN	Initialization flag for transition phase	EGTRAN	ND	D
ISLECT	Entry guidance subphase counter	EGEXEC, ENT DIP, TLM, MEDS FC GNC XFER	ND	I
T2	Constant drag level to reach target	ENT DIP, TLM, EGCOMN	ft/sec ²	F
DREFP	Drag reference used in controller	ENT DIP, TLM	ft/sec ²	F
DZOLD	Previous value of delta azimuth	EGLODVCMD	rad	F
D23	Reference drag level of equilibrium glide and anchor drag level of temperature control phase	EGRP, TLM	ft/sec ²	F
RK2ROL	Roll direction	EGLODVCMD, EGROLCMD, TLM	ND	F
RPT	Desired transition range	EGCOMN, EGRP, EGREF4, TLM	nmi	F
VSIT2	VS1 ²	EGRP, EGREF	ft ² /sec ²	F
VCG	Equilibrium glide-constant drag boundary velocity	EGEXEC, EGRP, TLM	ft/sec	F
VSAT2	VSAT ²	EGCOMN, EGTRAN, EGLODVCMD	ft ² /sec ²	F
VQ2	VQ ²	EGCOMN, EGRP	ft ² /sec ²	F
DX(1)	Normalized drag at VB1	EGRP	ND	F
VO(1)	Lower velocity bound for D-V quadratic 1	EGRP	ft/sec	F
VX(1)	Velocity where dD/dV = 0 for D-V quadratic 1	EGRP	ft/sec	F
VF(1)	Upper velocity bound for D-V quadratic 1	EGRP	ft/sec	F
A(1)	Parameter for D-V quadratic 1	EGRP	ND	F
VO(2)	Lower velocity bound for D-V quadratic 2	EGRP	ft/sec	F
VX(2)	Velocity where dD/dV = 0 for D-V quadratic 2	EGRP	ft/sec	F
A(2)	Parameter for D-V quadratic 2	EGRP	ND	F
VB2	VB1 ²	EGRP, EGREF	ft ² /sec ²	F

Table 4.5.2.4-1. EGINIT Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
RCG1	Constant component of RCG	EGRP	nmi	F
IALP	ALPCMD segment counter	EGALPCMD	ND	I
START	Entry guidance first pass flag	EGEXEC	ND	D
DLRDOT	\dot{h} feedback	EGLODVCMD, TLM	ft/sec	F
LMFLG	\dot{h} lockout flag for saturated roll command	EGLODVCMD	ND	I
VTRB	\dot{h} feedback velocity lockout	EDLODVCMD	ft/sec	
DDP	Past value of DD	EGLODVCMD	ft/sec ²	F
RK2RLP	Past value of RK2ROL	EGLODVCMD	ND	F
EG_END	Entry guidance termination flag	MSC, TLM	ND	D
ICT	Initial value of α modulation flag	EGGNSLCT, EGLODVCMD, EGROLCMD	ND	I
IDBCHG	Lateral deadband flag	EGLODVCMD	ND	D
DLRDTZ	\dot{h} feedback zero flag	EGLODVCMD	ND	D
VNOALP	α modulation velocity constraint	EGLODVCMD, EGROLCMD	ft/sec	F
VYLMAX	Velocity for ALMN4 limit	EGLODVCMD	ft/sec	F
RP_START	EGRP first pass initialization flag	EGRP	ND	D
VC16	Velocity to enable drag bias term	EGGNSLCT	ft/sec	F
VRDT	Velocity to initiate \dot{h} correction processing	EGLODVCMD	ft/sec	F
ITAL1	TAL 1st pass flag	EGALPCMD	ND	D
DYL	Auto PTI DELAZ deadband	EGLODVCMD	rad	F
DYLN	Auto PTI DELAZ deadband counter	EGLODVCMD	ND	I
VTRB1	Auto PTI velocity lockout	EGLODVCMD	ft/sec	F
ROLLC_ FLG	Initial roll command flag	EGCOMN	ND	D
ROLLC(1)	Commanded roll angle about the X body axis	EGCOMN	deg	F
VTURN	Low-energy logic: maximum velocity for non zero roll commands	EGLODVCMD	ft/sec	F
VI_INIT	Low-energy logic: initial value of inertial velocity	EGROLCMD	ft/sec	F
ALPHPO_ HI	Low-energy logic: maximum initial pullout alpha command limit	EGROLCMD	deg	F
ILEINT	Low-energy logic first pass flag	EGEXEC	ND	I
IRDOT	Low-energy logic: pullout completion flag	EGROLCMD	ND	I

Table 4.5.2.4-2. EGINIT I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0437C	VQ	Predicted end velocity for constant drag phase		ft/sec	MX
V97U5423C	NAUTMI _PER_FT	Feet to nautical miles conversion factor	1.6457884 E-4	nmi/ft	X
V97U0227C	ETRAN	Energy level at start of transition phase		ft ² /sec ²	MX
V97U0160C	EEF4	Final reference energy level in transition		ft ² /sec ²	MX
V97U0121C	DF	Final drag level in transition		ft/sec ²	MX
V97U0009C	ALFM	Desired constant drag level		ft/sec ²	MX
V97U0441C	VTRAN	Transition velocity		ft/sec	MX
V97U0392C	RPT1	Range bias term		nmi	MX
V97U0439C	VSAT	Local circular orbit velocity	25,766.2	ft/sec	K
V97U0440C	VS1	Reference velocity for equilibrium glide		ft/sec	MX
V97U0007C	AK	Parameter in D23-VB1 temperature control quadratic		ND	MX
V97U0430C	VB1	Temperature control – equilibrium glide phase boundary velocity		ft/sec	MX
V97U0421C	VA	Velocity where dD/dV = 0 in D23-VB1 temperature control quadratic		ft/sec	MX
V97U0428C	VA1	Intersection velocity between quadratic segments in temperature control phase		ft/sec	MX
V97U0429C	VA2	Velocity where dD/dV = 0 in D24-VA1 temperature control quadratic		ft/sec	MX
V97U0008C	AK1	Parameter in D24-VA1 temperature control quadratic		ND	MX
V97U0321C	NALP	Number of ALPCMD segment boundaries		ND	SX
V97U0141C	D230	Initial value of D23		ft/sec ²	MX
V99U7402C	NALP1	Number of ALPCMD segments for TAL		ND	MX
V99U6203C	DYL1	Auto PTI DELAZ deadband Number 1		rad	MX
V97U2020C	ALPHPO (2)	Low-energy logic: maximum initial pullout alpha command for small heading errors		deg	MX
V97U2032C	ALPHPO (3)	Low-energy logic: maximum initial pullout alpha command for large heading errors		deg	MX
V97U2033C	DLZ_LM_ ALP_HI	Low-energy logic: heading error limit to establish maximum initial pullout alpha command		rad	MX
V97U9528C	VTURN1	Low-energy logic: VI coefficient for VTURN equation		ND	MX
V97U9529C	VTURN2	Low-energy logic: constant for VTURN equation		ft/sec	MX

4.5.2.5 Entry Guidance Common Computations (EGCOMN).

EGCOMN computes several variables used in the rest of the entry guidance software.

A. Detailed Requirements. The following variables are computed:

Limited lift/drag ratio	$XLOD = \text{MAX}(\text{SCALAR}(\text{LOD}, \text{LODMIN}))$
Vertical lift acceleration for equilibrium glide	$T1 = \text{GO} (\text{VI}^2/\text{VSAT2}-1.)$
Previous value of T2	$T2\text{OLD} = T2$
Relative velocity squared	$\text{VE2} = \text{VE}^2$
Energy/mass	$\text{EEF} = \text{GO HLS} + \text{VE2}/2.$
Pseudo energy/mass	$\text{CAG} = 2. \text{GO HS} + \text{VE2}$
Auto PTI h guidance acceptance check	If $\text{ABS}(\text{VERTAC}) \geq \text{VERTACLIM}$, then $\text{GUID_ACCEP} = \text{FALSE}$; else $\text{GUID_ACCEP} = \text{TRUE}$

If $\text{ISLECT} = 5$, EGCOMN is then exited. If $\text{ISLECT} < 5$, the constant drag level to reach the start of the transition phase at the desired range RPT is computed next, dependent on whether or not the low-energy logic is engaged:

If $\text{ICNTAL} = \text{OFF}$,
then $T2 = \text{NAUTMI_PER_FT} (\text{VE2} - \text{VQ2}) / (2. (\text{TRANGE} - \text{RPT}))$
else $T2 = \text{NAUTMI_PER_FT} (\text{VE2} - \text{VQ2}) / (2. (\text{TRNGLE} - \text{RPT}))$

The rate of change of T2 is then computed:

$$T2\text{DOT} = (\text{T2}-\text{T2OLD})/\text{DTEGD}$$

Next, if $\text{VE} < \text{VTRAN} + \text{DELV}$, the slope of the drag-energy curve, an altitude rate reference, and the reference drag test value for use in EGEXEC to enable a transition to $\text{ISLECT} = 5$ are computed:

$$C1 = (\text{T2} - \text{DF})/(\text{ETRAN} - \text{EEF4})$$

$$\text{RDTRFT} = -(\text{C1} (\text{GO HLS} - \text{EEF4}) + \text{DF}) 2. \text{VE HS}/\text{CAG}$$

$$\text{DREFP5} = \text{DF} + (\text{EEF} - \text{EEF4}) \text{C1} + \text{GS4} (\text{RDTREF} - \text{RDTRFT})$$

Finally, in order to prevent an incorrect initial roll direction because of a change in the sign of DELAZ after EGINIT is executed, DELAZ is rechecked and RK2ROL is reset. This logic is disabled the first time the magnitude of the guidance roll command is greater than RLCMIN.

If $\text{ROLLC_FLG} = 1$ or $\text{ABS}(\text{ROLLC}(1)) > \text{RLCMIN}$,

then $\text{ROLLC_FLG} = 1$
else $\text{RK2ROL} = -\text{SIGN}(\text{DELAZ})$

EGCOMN is then exited.

B. Interface Requirements. The EGCOMN input/output parameters are listed in Table 4.5.2.5-1. The I-loads/constants are listed in Table 4.5.2.5-2.

C. Processing Requirements. EGCOMN is processed at the entry guidance rate before all other functions except EGSCALEHT and EGINIT.

D. Initialization Requirements. None.

Table 4.5.2.5-1. EGCOMN Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
VERTAC	Vertical Acceleration	NAV	ft/sec ²	F
LOD	Lift/drag ratio	NAV	ND	F
VI	Vehicle inertial speed	NAV	ft/sec	F
T2	Constant drag level to reach target	EGINIT	ft/sec ²	F
ISLECT	Entry guidance phase counter	EGEXEC	ND	I
VE	Ground relative velocity magnitude	NAV	ft/sec	F
VQ2	VQ ²	EGINIT	ft ² /sec ²	F
HLS	Altitude above runway	NAV	ft	F
HS	Atmospheric density scale height	EGSCALEHT	ft	F
VSAT2	VSAT ²	EGINIT	ft ² /sec ²	F
RDTREF	Altitude rate reference	EGREF, EGREF4, EGTRAN	ft/sec	F
TRANGE	Range to the runway threshold	NAV	nmi	F
RPT	Desired transition range	EGINIT	nmi	F
DELAZ	Orbiter heading deviation from HAC tangency	NAV	rad	F
ROLLC_ FLG	Initial roll command flag	EGINIT, EGPEP	ND	D
ROLLC(1)	Commanded roll angle about the X body axis	EGINIT, EGROLCMD	deg	F
ICNTAL	Low-energy logic engagement discrete	EGEXEC, EGROLCMD	ND	D
TRNGLE	Low-energy logic: biased range to the runway threshold	EGEXEC	nmi	F
OUTPUTS				
XLOD	Limited lift/drag ratio	EGPEP, EGLODVCMD, EGROLCMD, TLM	ND	F
T1	Vertical lift acceleration for equilibrium glide	EGLODVCMD, TLM	ft/sec ²	F
VE2	VE ²	EGRP, EGREF, EGTRAN	ft ² /sec ²	F
EEF	Current energy/mass	EGTRAN, TLM	ft ² /sec ²	F
CAG	Pseudo energy/mass used in transition L/D reference	EGTRAN	ft ² /sec ²	F

Table 4.5.2.5-1. EGCOMN Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
T2	Constant drag level to reach target	ENT DIP, TLM, EGEXEC, EGREF, EGREF4	ft/sec ²	F
RK2ROL	Roll command direction	EGLODVCMD, TLM	ND	F
T2DOT	Time rate of change of T2	EGRP	ft/sec ³	F
DREFP5	Test value of DREFP for transition to Phase 5	EGEXEC, TLM	ft/sec ²	F
GUID_ACCEP	Auto PTI acceptable discrete	PTI (AEROJET DAP)	ND	D

Table 4.5.2.5-2. EGCOMN I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V90A7622C	GO	Earth gravitational acceleration constant	32.174049	ft/sec ²	X
V97U5423C	NAUTMI_PER_FT	Conversion factor from feet to nautical miles	1.6457884E-4	nmi/ft	X
V97U0121C	DF	Final drag level in transition		ft/sec ²	MX
V97U6100C	DTEGD	Entry guidance cycle interval	1.92	sec	X
V97U0160C	EEF4	Final reference energy level in transition		ft ² /sec ²	MX
V97U0227C	ETRAN	Energy level at start of transition phase		ft ² /sec ²	MX
V97U0441C	VTRAN	Nominal velocity at start of transition phase		ft/sec	MX
V97U0118C	DELV	Phase transfer velocity bias		ft/sec	SX
V97U0316C	LODMIN	Minimum lift/drag ratio		ND	SX
V97U0262C	GS4	Factor used in roll command smoothing logic		sec ⁻¹	MX
V99U6336C	VERT_ACLIM	Vertical acceleration limit for AUTO PTI		ft/sec ²	MX
V99U6985C	RLCMIN	Minimum initial roll command to disable roll direction check		deg	SX

4.5.2.6 Entry Guidance Pre-entry Phase (EGPEP).

EGPEP provides attitude commands prior to the initiation of ranging.

A. Detailed Requirements. Prior to the initiation of closed-loop ranging, the EGPEP function effectively provides the pre-entry phase roll command(s) by establishing vertical L/D commands as derived from the pre-entry, mission dependent, bank angle command (PREBNK). Vertical L/D commands are generated from the following equations:

$$\text{LODX} = \text{XLOD} \cos(\text{PREBNK}/\text{DEG_PER_RAD})$$

$$\text{LODV} = \text{LODX}$$

For a non-TAL entry that requires a prebank, the roll direction check is disabled when the vehicle body roll attitude exceeds an I-loaded value.

$$\text{If } \text{ITAL} = 0 \text{ and } \text{ABS}(\text{ROLL}) > \text{ROLLMIN},$$

$$\text{then } \text{ROLLC_FLG} = 1$$

PREBNK is the desired bank angle from the mission memory load. XLOD is the navigation-derived L/D, limited to \geq LODMIN in EGCOMN. The angle-of-attack command for the pre-entry phase is computed in EGALPCMD. The pre-entry phase is terminated by EGEXEC when the sensed total acceleration becomes greater than ASTART.

B. Interface Requirements. The input and output parameters of EGPEP are listed in Table 4.5.2.6-1. The I-loads/constants used in EGPEP are listed in Table 4.5.2.6-2.

C. Processing Requirements. The EGPEP function is processed at entry guidance rate when ISLECT = 1.

D. Initialization Requirements. None.

Table 4.5.2.6-1. EGPEP Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
ITAL	Transoceanic abort discrete	MSC	ND	D
ROLL	Body roll attitude	A/E ATT PROC	deg	F
XLOD	Limited lift/drag ratio	EGCOMN	ND	F
OUTPUTS				
LODV	Desired vertical L/D ratio	EGROLCMD, TLM	ND	F
LODX	Desired, unlimited vertical L/D ratio	EGROLCMD	ND	F
ROLLC_FLG	Initial roll command flag	EGCOMN	ND	D

Table 4.5.2.6-2. EGPEP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0112C	DEG_PER_RAD	Radians to degrees conversion factor	57.2957795131	deg/rad	X
V97U0349C	PREBNK	Pre-entry bank angle command		deg	MX
V99U6986C	ROLLMIN	Minimum initial roll angle to disable roll direction check		deg	SX

4.5.2.7 Entry Guidance Range Prediction (EGRP).

The EGRP function serves as the range predictor during the temperature control and equilibrium glide phases. The range prediction is then used to determine the proper drag level during these phases to achieve the desired range at the entry-TAEM interface.

In order to determine the proper drag-velocity profile for range control, a range prediction is made of the entire entry trajectory. This is accomplished by using five drag-velocity segments: two during the temperature control phase, one during the equilibrium glide phase, one during the constant drag phase, and a constant range value during the transition phase. The temperature control, equilibrium glide, and constant drag phase range segments are computed in EGRP. The range value for the transition phase, RPT, is computed in EGINIT and is constant in order to provide a nominal transition range at the transition velocity interface, VTRAN. Once the transition phase is entered, the transition range prediction is updated in the EGTRAN function to meet the range requirements.

The drag-velocity segments during the temperature control, equilibrium glide, and constant drag phases are anchored at specific velocity points as illustrated in Figure 4.5.2.7-1.

The range for the temperature control phase is predicted along two quadratic drag-velocity segments anchored at VB1 and at VA1. For the equilibrium glide segment, the range is predicted between VB1 and VCG, the computed intersection point between the equilibrium glide phase and constant drag phase; while for the constant drag segment, the range is predicted between VCG and VQ. In all cases, the entire drag-velocity profile is anchored at a drag level of D23 at a velocity of VB. During the temperature control phase, VB is defined as VB1; and during the equilibrium glide phase, VB is defined as the current relative velocity. Therefore,

$$\text{If } VE > VB1, VB = VB1$$

$$\text{If } VE \leq VB1, VB = VE$$

In the equilibrium glide phase, as the drag profile approaches the desired constant drag level, the locus of the equilibrium glide drag reference parameter may wander from a precise equilibrium glide profile shape trying to drive T2 to precisely ALFM, the desired constant drag level. In order to provide a more uniform equilibrium glide drag profile at the junction point between the equilibrium glide and the constant drag phases, the equilibrium glide reference profile is "frozen" when the rate of change of T2 is near zero. This is illustrated in Figure 4.5.2.7-2. This is accomplished by freezing VB at the current value of VE when T2DOT becomes less than DT2MIN and when VE is less than VCG + DELV.

A. Detailed Requirements. The predicted range for the temperature control phase initially consists of two segments corresponding to the two quadratic drag-velocity profiles. The velocity regime of the first segment extends from VB1 to the drag profile intersection velocity, VA1. The second segment extends from VA1 to the current velocity, VE. When VE has decreased to \leq VA1, only one segment is computed, from VB1 to VE.

The quadratic drag-velocity profiles have the form:

$$D = C + C'VE + C''VE^2$$

For the quadratic anchored at VB1 and D23, the quadratic coefficients are defined as follows:

$$C'' = C23 = - AK D23 / (2. (VA - VB) VB)$$

$$C' = C22 = - 2. VA C23$$

$$C = C21 = D23 - C22 VB - C23 VB^2$$

The other quadratic, anchored at VA1 and D24, is computed as follows:

$$D24 = C21 + C22 VA1 + C23 VA1^2$$

$$C'' = C33 = - AK1 D24 / (2. (VA2 - VA1) VA1)$$

$$C' = C32 = - 2. VA2 C33$$

$$C = C31 = D24 - C32 VA1 - C33 VA1^2$$

The predicted range for each segment is obtained by evaluating the range integral, which will be discussed shortly.

The quadratic drag profile coefficients can be computed as follows:

1. Since the six constants C23, . . . , C31 have the common factor D23, they will be computed for a D23 = 1.0. This procedure simplifies updating D23 after the range components are computed.
2. Denote

$$\begin{array}{ll} DX(1) = 1. & DX(2) = D24/D23 \\ VO(1) = VB1 & VO(2) = VA1 \\ VX(1) = VA & VX(2) = VA2 \\ A(1) = AK & A(2) = AK1 \end{array}$$

where the subscript (1) refers to the VB1 – VA1 segment, subscript (2) refers to the VA1 – VE segment, and VB = VB1 when VE > VB1. The variables listed above are set in EGINIT except for DX(2). The quadratic coefficients for each segment are then computed by:

$$CQ3(I) \equiv C''/D23 = - A(I) DX(I)/(2. (VX(I) - VO(I)) VO(I))$$

$$CQ2(I) \equiv C'/D23 = - 2. VX(I) CQ3(I)$$

$$CQ1(I) \equiv C/D23 = DX(I) - VO(I) (CQ2(I) + CQ3(I) VO(I))$$

where

$$\begin{aligned} DX(2) &= D24/D23 \\ &= CQ1(1) + VA1 (CQ2(1) + CQ3(1) VA1) \end{aligned}$$

The CQX(I) coefficients remain unchanged as long as the vehicle remains in the temperature control phase ($VE > VB1$), and therefore need only be computed once. These variables are used to compute the drag and altitude rate reference parameters in the EGREF function when $VE > VB1$.

Once the quadratic coefficients have been defined, the range segments are computed by evaluating the range integral. The basic range differential is

$$dR = (V/D)dV$$

For the two temperature control range segments,

$$D = D23(CQ1(I) + CQ2(I) VE + CQ3(I) VE^2)$$

thus, we must evaluate for each velocity segment the integral (for $D23 = 1.0$)

$$RF(I) = \int_{VO(I)}^{VF(I)} \frac{dVE}{CQ1(I) / VE + CQ2(I) + CQ3(I) VE}$$

If $VE > VA1$, the upper limits of integration are $VF(1) = VA1$ (set in EGINIT) and $VF(2) = VE$. If $VE \leq VA1$, $VF(1) = VE$ and $RF(2) = 0$. $RF(1)$ does not change as long as $VE > VA1$. Thus, after both range segments have been computed on the initial pass through EGRP, only one segment need be computed on each guidance cycle thereafter.

The above integral can be evaluated analytically, but a numerical integration algorithm that gives adequately precise values is used for simplicity. The algorithm is

$$\int_{x_o}^{x_o + h} y(x) dx = \frac{h}{98} \left[27 y \left(x_o + \frac{h}{9} \right) + 44 y \left(x_o + \frac{h}{2} \right) + 27 y \left(x_o + \frac{8h}{9} \right) \right]$$

This is implemented by the following equations:

$$V(1) = (8. VO(I) + VF(I))/9.$$

$$V(2) = (VO(I) + VF(I))/2.$$

$$V(3) = VO(I) + VF(I) - V(1)$$

$$Q(J) = CQ1(I)/V(J) + CQ2(I) + CQ3(I) V(J) \quad (J = 1 \text{ to } 3)$$

$$RF(I) = (27./Q(1) + 44./Q(2) + 27./Q(3)) (VF(I) - VO(I))/98.$$

Processing requirements for EGRP which satisfy the computational requisites for the above obfuscation of velocity segments, range integrals, and subsequent dependencies will now be described.

The number of applicable velocity segments, N, is first determined based on the input ground relative velocity magnitude (VE). When only the first segment is required (i.e., $VE \leq VA1$), the range integral for the second velocity segment (i.e., $VE > VA1$) is set to zero. Note: N will also be used for the reference parameter calculations in EGREF.

If $VE > VA1$, then $N = 2$
else $N = 1$ and $RF(2) = 0.0$

The current relative velocity magnitude is then used to define the “Nth” range integral upper velocity limit.

$$VF(N) = VE$$

EGRP first pass only computational requirements are now performed if the EGRP first pass flag, RP_START , is “OFF”.

The quadratic drag profile coefficients are computed.

Do for $I = 1$ to 2 :

$$CQ3(I) = -A(I) DX(I) / (2. (VX(I) - VO(I)) VO(I))$$

$$CQ2(I) = -2. VX(I) CQ3(I)$$

$$CQ1(I) = DX(I) - VO(I) (CQ2(I) + CQ3(I) VO(I))$$

If $I < 2$, then compute $DX(2)$, the normalized drag at $VA1$.

$$DX(2) = D24 / D23$$

$$= CQ1(1) + VA1 (CQ2(1) + CQ3(1) VA1)$$

After determination of the $I = 1$ & 2 drag profile coefficients as well as $DX(2)$, the velocity segment indicator (K) is set to 1 .

$$K = 1$$

The EGRP first pass flag is now set to “ON”.

$$RP_START = ON$$

This completes the EGRP first pass initialization requirements.

If this is not the initial execution cycle for EGRP, the velocity segment indicator index is set to the previously determined number of applicable velocity segments.

$$K = N$$

The EGRP intermediate velocity segment integrals may now be computed as follows:

Do for $I = K$ to N ,

$$V(1) = (8. VO(I) + VF(I)) / 9.$$

$$V(2) = (VO(I) + VF(I)) / 2.$$

$$V(3) = VO(I) + VF(I) - V(1)$$

Do for $J = 1$ to 3 ,

$$Q(J) = CQ1(I) / V(J) + CQ2(I) + CQ3(I) V(J)$$

$$RF(I) = (27. / Q(1) + 44. / Q(2) + 27. / Q(3)) (VF(I) - VO(I)) / 98.$$

The total temperature control phase range is set to zero if the relative velocity is less than VB1; otherwise, the total temperature control range (in nautical miles) is computed for a D23 value of 1.0. Note that the predicted temperature control range, RFF, is RFF1 / D23.

If $VE < VB1$, then $RFF1 = 0.0$

else $RFF1 = NAUTMI_PER_FT (RF(1) + RF(2))$

The primary purpose for the remaining EGRP processing requirements is to update D23 for use in computing the reference drag and altitude rate in EGREF as well as for determination of the reference L/D in EGLODVCMD. Since D23 should only be updated when $T2DOT > DT2MIN$ or $VE > VCG + DELV$, these tests are first made; and if true, the following EGRP computations are performed. Otherwise, EGRP is exited.

To summarize, the remaining EGRP computational requirements provide the following:

- (1) Computation of the equilibrium glide and constant drag range segments (after first determining the Phase 3 – 4 intersection velocity, VCG),
- (2) Computation of the partial of range with respect to D23 (DRDD) for entry CRT display availability, and
- (3) A D23 update (for subsequent use in EGREF) which is performed to correct for any known ranging errors.

The velocity, VCG, where the equilibrium glide drag is equal to or intersects the desired constant drag level, ALFM, will be determined. The equilibrium glide drag level is proportional to $VS1^2 - VE^2$ and is equal to D23 at $VE = VB$, so that

$$(VS1^2 - VCG^2) / ALFM = (VS1^2 - VB^2) / D23$$

The above defines VCG for nominal conditions. However, VCG will be limited to be no less than VQ, the lower velocity bound for the constant drag phase. Once VCG is determined, then the equilibrium glide range REQ (from VB to VCG) and the constant drag range RCG (from VCG to VQ) may be derived from

$$REQ = NAUTMI_PER_FT (VS1^2 - VB^2) \ln(D(VCG) / D23) / (2. D23)$$

$$RCG = NAUTMI_PER_FT (VCG^2 - VQ^2) / (2. ALFM)$$

where D(VCG) denotes the equilibrium glide drag level at VCG as follows:

$$D(VCG) = ALFM \text{ if } VCG > VQ, \text{ and } D(VCG) \leq ALFM \text{ if } D23 = D23L.$$

Specific equation processing requirements for the determination of VCG, REQ, and RCG are defined as follows:

$$\text{If } VE < VB1, \text{ then } VB2 = VE2$$

$$VCG = VQ$$

$$D23L = ALFM (VSIT2 - VB2) / (VSIT2 - VQ2)$$

If $D23 > D23L$,

$$\text{then } VCG = \text{SQRT}(VSIT2 - D23L (VSIT2 - VQ2) / D23)$$

$$\text{else } D23 = D23L$$

$$A2 = \text{NAUTMI_PER_FT} (VSIT2 - VB2) / 2.$$

$$REQ1 = A2 \text{ LOG}(ALFM / D23)$$

$$RCG = RCG1 - A2 / D23$$

Note: $RCG1 = \text{NAUTMI_PER_FT} (VSIT2 - VQ2) / (2. ALFM)$ as computed in EGINIT and $REQ1 = D23 REQ$

A first-order update of D23 is now obtained by solving the range equation, $\text{TRANGE} = (RFF1 + REQ1) / D23 + RCG + RPT$, for D23. Note: if the low-energy logic is engaged ($\text{ICNTAL} = \text{ON}$), TRNGLE rather than TRANGE will be used. The equations are:

$$R231 = RFF1 + REQ1$$

If $\text{ICNTAL} = \text{OFF}$,

$$\text{then } R23 = \text{TRANGE} - RCG - RPT$$

$$\text{else } R23 = \text{TRNGLE} - RCG - RPT$$

$$D231 = R231 / R23$$

The partial of range with respect to D23 is then computed by:

$$\begin{aligned} \text{DRDD} &= -(RFF1 + REQ1) / D23^2 \\ &= -R23 / D231 \end{aligned}$$

To obtain DRDD, the use of $-R23 / D231$ is recommended.

Finally, a MacLaurin series expansion of D23, viz.,

$$D23 = D230 + \sum_{n=1}^{\infty} \frac{1}{n!} \frac{d^n D23}{dR^n} (R23 - R231 / D230)^n$$

(where D230 is the initial value of D23), yields the second-order update equation

$$D23 = D231 + A2 (1. - D23 / D231)^2 / (2. R23)$$

The second order correction term (which accounts for the effect of the change in VCG with D23 on range) should only be processed when D231 is greater or equal to D23L. Otherwise, D23 is limited to be no less than E1. This logic is implemented by:

If $D231 \geq D23L$,

$$\text{then } D23 = D231 + A2 (1. - D23 / D231)^2 / (2. R23)$$

$$\text{else } D23 = \text{MAX}(\text{SCALAR}(D231, E1))$$

This completes all processing requirements for the EGRP function.

B. Interface Requirements. The input/output parameters for EGRP are listed in Table 4.5.2.7-1. The I-loads/constants are listed in Table 4.5.2.7-2.

C. Processing Requirements. EGRP is executed at the entry guidance rate when ISLECT is two or three.

D. Initialization Requirements. None.

E. Supplemental Information. The range partial, DRDD, which is computed for CRT display utilization will not be updated after D23 is “frozen”.

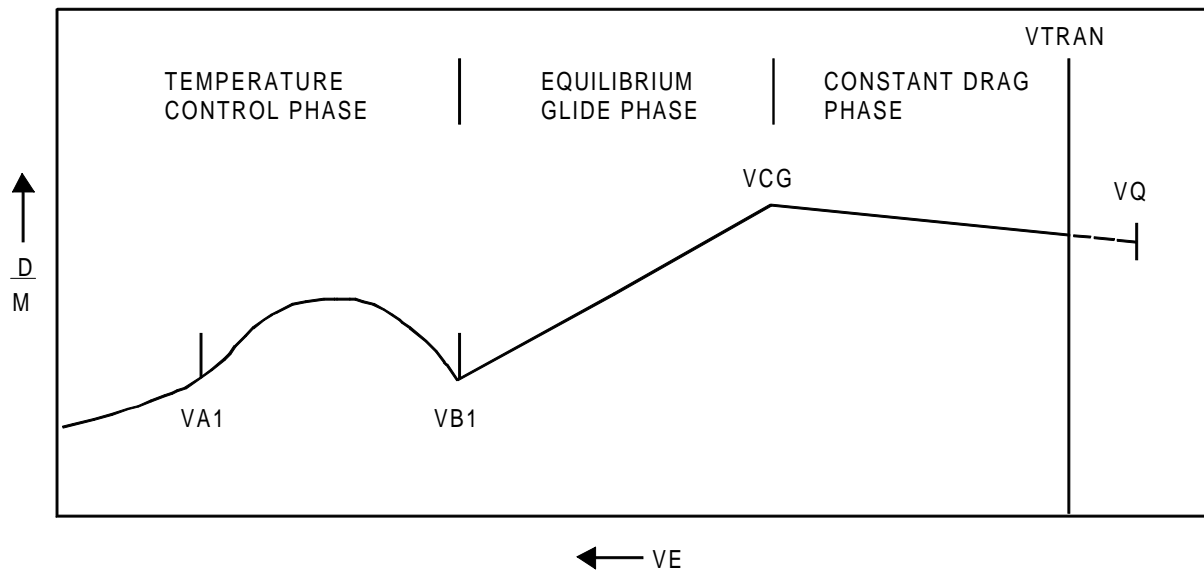
The second-order correction term to D23 may be possibly improved in accuracy by changing

$$(1. - D23 / D231)^2 \quad \text{to} \quad (1. - D231 / D23)^2$$

The theoretically correct expression has been retained to avoid possible problems with values different from test case scenarios used to evaluate the accuracy of this correction term.

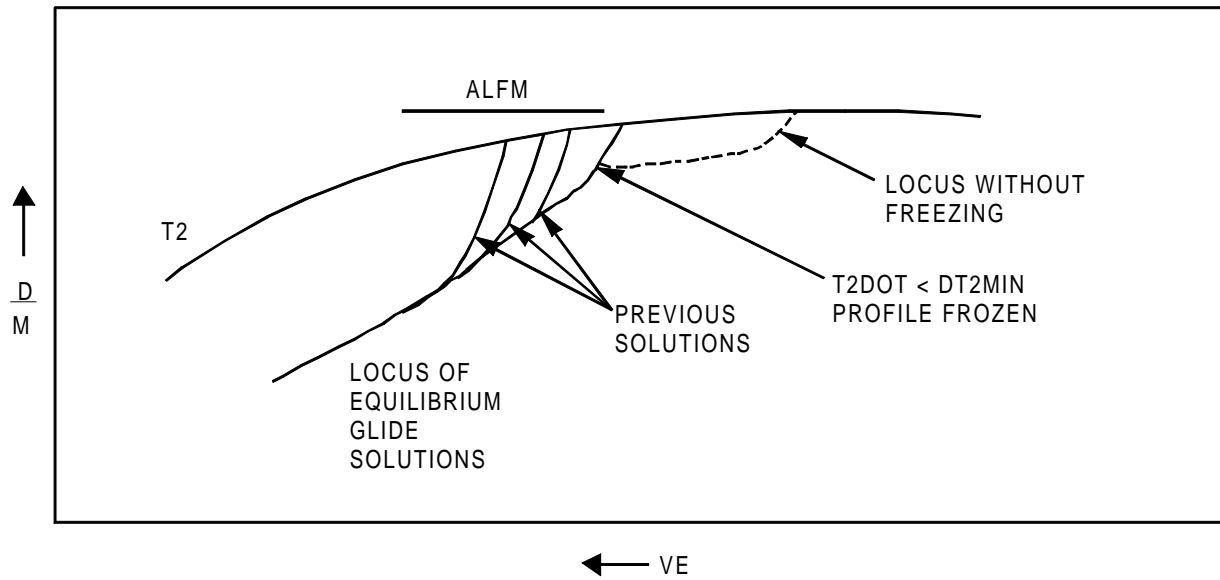
The D23 update equation as derived from the MacLaurin series expansion for D23 only employs the second order correction term. For the vast majority of equilibrium glide conditions, the omission of higher ordered correction terms (i.e., third order, fourth order, etc.) will not affect guidance operations in any discernible fashion. There is, though, a potential for a short-term, D23 divergence condition if a significant increase in the range-to-go should occur during the equilibrium glide phase particularly as the guidance approaches the equilibrium glide to constant drag phase transition point. Examples of range-to-go transients which might “trigger” this short-lived divergence characteristic are a runway redesignation, HAC approach reselection (e.g., straight-in to overhead), or a delta state update to the Nav state vector which results in a sufficient increase in the Nav output of range-to-go. Corrective changes to the FSSR prescribed D23 requirements specifications have been established, but these changes are not felt warranted given:

- (1) The low probability of occurrence,
- (2) Implementation of flight rules which minimize exposure to range transients in this particular flight regime, and
- (3) The short-lived nature of the described D23 divergence characteristic which has not yet been identified as inducing any deteriorative effects on descent G&C or trajectory operations.



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 4.5.2.7-1. Drag-Velocity Segments Used in Range Predictions



(THIS FIGURE INCLUDED FOR ILLUSTRATIVE PURPOSES ONLY)

FIGURE 4.5.2.7-2. Freezing of Equilibrium Glide Profile

Table 4.5.2.7-1. EGRP Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
RP_START	EGRP first pass initialization flag	EGINIT	ND	D
DX(I)	Normalized drag at VB1	EGINIT	ND	F
A(I)	Parameter for D-V quadratic I	EGINIT	ND	F
I = 1,2				
VO(I)	Lower velocity bound for D-V quadratic I	EGINIT	ft/sec	F
I = 1,2				
VX(I)	Velocity where dD/dV = 0 for D-V quadratic I	EGINIT	ft/sec	F
I = 1,2				
VF(1)	Upper velocity bound for D-V quadratic I	EGINIT	ft/sec	F
T2DOT	Time rate of change of T2	EGCOMN	ft/sec ³	F
VCG	Phase 3/4 boundary velocity	EGINIT	ft/sec	F
VE2	VE ²	EGCOMN	ft ² /sec ²	F
VB2	VB1 ²	EGINIT	ft ² /sec ²	F
VSIT2	VS1 ²	EGINIT	ft ² /sec ²	F
VQ2	VQ ²	EGINIT	ft ² /sec ²	F
D23	Reference drag level at VB1	EGINIT	ft/sec ²	F
RCG1	Constant components of RCG	EGINIT	nmi	F
TRANGE	Range to runway threshold	NAV	nmi	F
RPT	Desired range at VQ	EGINIT	nmi	F
ICNTAL	Low-energy logic engagement discrete	EGEXEC, EGROLCMD	ND	D
TRNGLE	Low-energy logic: biased range to the runway threshold	EGEXEC	nmi	F
OUTPUTS				
N	Number of temperature control range segments being computed	EGREF	ND	I
CQ1(I)	Constant in drag – velocity quadratic for Ith range segment	EGREF	ND	F
(I = 1,2)				
CQ2(I)	VE coefficient in drag – velocity quadratic for Ith range segment	EGREF	sec/ft	F
(I = 1,2)				
CQ3(I)	VE2 coefficient in drag – velocity quadratic for Ith range segment	EGREF	sec ² /ft ²	F
(I = 1,2)				
VB2	VB1 ²	EGREF	ft ² /sec ²	F
VCG	Predicted intersection velocity between the equilibrium glide and constant drag phases	EGEXEC, TLM	ft/sec	F
D23	Reference drag of equilibrium glide and anchor drag level of temperature control phase	EGREF, TLM	ft/sec ²	F
DRDD	Derivative of range with respect to drag	ENT DIP, TLM	nmi/(ft/sec ²)	F
D231	First order update value of drag ref	TLM	ft/sec ²	F

Table 4.5.2.7-2. EGRP I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0428C	VA1	Boundary velocity between quadratic segments in temperature control phase		ft/sec	MX
V97U5423C	NAUTMI_PER_FT	Conversion factor from feet to nautical miles	1.6457884E-4	nmi/ft	X
V97U0430C	VB1	Temperature control – equilibrium glide phase boundary velocity		ft/sec	MX
V97U0140C	DT2MIN	Test value for T2DOT		ft/sec ³	SX
V97U0437C	VQ	Predicted end velocity for constant drag phase		ft/sec	MX
V97U0009C	ALFM	Desired constant drag level		ft/sec ²	MX
V97U0228C	E1	Minimum value of D23	0.01	ft/sec ²	K
V97U0118C	DELV	Phase transfer velocity bias		ft/sec	SX

4.5.2.8 Entry Guidance Reference Parameters (EGREF).

In order to control the orbiter to the desired drag–velocity profile for satisfaction of ranging requirements, a roll angle command will be generated from a drag reference, altitude rate reference, and L/D reference. The precise command controller equations as necessary to generate this roll angle command are presented in the EGLODVCMD function. The purpose of EGREF is to provide the drag and altitude rate references for both the temperature control and equilibrium glide phases that will be subsequently employed by EGLODVCMD to derive the L/D command(s) as then used by EGROLCMD to compute the entry guidance roll command(s).

A. Detailed Requirements. The drag reference during the temperature control phase is derived from the appropriate, EGRP computed, quadratic, drag–velocity segment as based on the current relative velocity, VE. Thus, when $VE \geq VB1$, the unscaled drag reference for the “Ith” velocity region ($I = 1$ to N where $N = 1$ or 2 as determined by EGRP) is

$$DREF(I) = CQ1(I) + VE (CQ2(I) + CQ3(I) VE)$$

The actual drag reference as to be used in the EGLODVCMD controller is then extracted from $DREF_I$ as scaled by D23, the anchor drag level for the temperature control phase, as follows:

$$DREFP = D23 DREF(I)$$

The altitude rate reference is derived from the basic drag rate equation for a constant drag coefficient, viz.,

$$\begin{aligned} \dot{D}/D &= \dot{\rho} / \rho + 2\dot{V}_E / V_E \\ &\approx -\dot{h}/h_S - 2D/V_E \end{aligned}$$

if the $g \sin \gamma$ term (1 to 2 percent of the drag) in \dot{V}_E is neglected. For the temperature control phase,

$$\begin{aligned} \dot{D} &= (2. CQ3(I) VE + CQ2(I)) D23 \dot{V}_E \\ \dot{D}/D &\approx -(2. CQ3(I) VE + CQ2(I)) D23 \\ &= -2. CQ3(I) (VE - VX(I)) D23 \end{aligned}$$

Combining terms results in the following expressions for deriving the temperature control phase altitude reference rate(s), HDTRF_I, and the dependent, scaled (via D23), altitude rate reference, RDTREF.

$$\begin{aligned} HDTRF(I) &= \dot{h}_{REF}/D23 \\ &= -HS (2. DREF(I)/VE - CQ2(I) - 2. CQ3(I) VE) \\ RDTREF &= D23 HDTRF(I) \end{aligned}$$

EGLODVCMD will then provide a correction to RDTREF to account for the rate of change of the drag coefficient, C_d , due to any changes in the sensed angle–of–attack.

To accomplish the above described temperature control reference parameter calculations, DREF(I) and HDTRF(I) may be computed through use of a DO loop (but only when $VE \geq VB1$) for $I = 1$ to N where N

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= 2 if $VE > VA1$ and $N = 1$ if $VE \leq VA1$. Determination of the value for N is performed by EGRP. Both sets (i.e., $I = 1, 2$) of reference parameters are computed when $VE > VA1$ (and $VE \geq VB1$) because in some cases a transition to the Subscript 1 set of parameters will be required even though the vehicle is in Subscript 2 ($VE > VA1$) velocity regime.

The logic for switching to the Subscript 1 reference parameters is based on a temperature control drag reference test value, DRF. If this test value (which includes a roll command smoothing term) is ≤ 0.0 , the $N = 1$ reference parameters will then be used to determine the EGLODVCMD required controller equation inputs. The calculations for DRF as well as the logical test for setting N to 1 are necessarily only performed when $VE > VA1$. When $VE \leq VA1$, N will have already been set to 1 by EGRP. The required switching logic computations are as follows:

$$DRF = DREF(2) - DREF(1)$$

$$DRF = DRF (DRF + (HDTRF(1) - HDTRF(2)) GS1)$$

$$\text{If } DRF \leq 0.0, \text{ then } N = 1$$

The controller drag, altitude rate, and L/D reference components are now computed as follows:

$$DREFP = D23 DREF(N)$$

$$RDTREF = D23 HDTRF(N)$$

$$C2 = D23 CQ2(N)$$

Next, the equilibrium glide phase reference parameters are computed if $VE < VA$. Additionally (if $VE < VA$), the determination for use of the Phase 3 parameters is made based on the current relative velocity and a Phase 3, roll smoothing, drag reference test parameter (DREFP3).

The equilibrium glide phase is assumed to be flown at a constant, vertical lift/drag ratio; thus, for a drag level $D23$ at a velocity VB , the desired drag level at VE is approximately

$$D_{ref} = D23 (VS1^2 - VE^2) / (VS1^2 - VB^2)$$

Analysis similar to that performed for the temperature control phase results in the following, desired, altitude rate reference.

$$\dot{h}_{ref} = -2 \cdot h_s D23 / ((1 - VB^2 / VS1^2) VE)$$

The drag and altitude rate references are computed as follows:

$$ALDCO = (1 - VB^2 / VS1^2) / D23$$

$$DREFP1 = (1 - VE^2 / VS1^2) / ALDCO$$

$$RDTRF1 = -2 \cdot HS / (VE ALDCO)$$

Note that ALDCO is the vertical lift/drag ratio at the reference velocity VB divided by g . The roll smoothing test parameter is next computed as:

$$DREFP3 = DREFP1 + GS2 (RDTREF - RDTRF1)$$

Use of the Phase 3 reference parameters will now occur if $VE < VA$ and ($DREFP3 > DREFP$ or $VE < VB1$) as follows:

$$DREFP = DREFP1$$

$$RDTREF = RDTRF1$$

$$C2 = 0.0$$

The test for $DREFP3 > DREFP$ is also used in EGEXEC to enable a transition from $ISLECT = 2$ to $ISLECT = 3$.

Finally, given completion of the preceding ($VE < VA$) equilibrium glide dependent processing, the initialization flag for transition, ITRAN, is set to 'ON' and DREFP4 is computed for use in EGEXEC to enable a transition to $ISLECT = 4$.

$$ITRAN = 'ON'$$

$$DREFP4 = T2 + GS3 (RDTREF + 2. HS T2/VE)$$

This completes the processing requirements for EGREF.

B. Interface Requirements. The input/output parameters for EGREF are listed in Table 4.5.2.8-1. The I-Loads are listed in Table 4.5.2.8-2.

C. Processing Requirements. EGREF is processed at the entry guidance rate when $ISLECT = 2$ or 3.

D. Initialization Requirements. None.

E. Supplemental Information. EGREF follows the function EGRP.

Table 4.5.2.8-1. EGREF Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
N	Number of temperature control range segments being computed	EGRP	ND	I
CQ1(I) (I = 1,2)	Constant on drag – velocity quadratic for Ith range segment	EGRP	ND	F
CQ2(I) (I = 1,2)	VE coefficient in drag – velocity quadratic for Ith range segment	EGRP	sec/ft	F
CQ3(I) (I = 1,2)	VE ² coefficient in drag – velocity quadratic for Ith range segment	EGRP	sec ² /ft ²	F
D23	Reference drag at equilibrium glide and anchor drag level at temperature control phase	EGRP	ft/sec ²	F
VB2	VB1 ²	EGINIT, EGRP	ft ² /sec ²	F
VSIT2	VS1 ²	EGINIT	ft ² /sec ²	F
VE2	VE ²	EGCOMN	ft ² /sec ²	F
HS	Atmospheric density scale height	EGSCALEHT	ft	F
T2	Constant drag level to reach target	EGCOMN	ft/sec ²	F
OUTPUTS				
DREFP	Drag reference used in controller	ENT DIP, TLM, EGEXEC, EGTRAN, EGGNSLCT, EGALPCMD, EGLODVCMD	ft/sec ²	F
RDTRF	Altitude rate reference	EGLODVCMD, EGCOMN	ft/sec	F
C2	Component of (L/D) reference used in controller	EGLODVCMD, TLM	sec ⁻¹	F
DREFP3	Test value of DREFP for transition to phase 3	EGEXEC, TLM	ft/sec ²	F
DREFP4	Test value of DREFP for transition to phase 4	EGEXEC, TLM	ft/sec ²	F
ITRAN	Initialization flag for transition phase	EGTRAN	ND	D
HDTRF(1)	Alt ref rate during temp cntl – 1	TLM	sec	F
HDTRF(2)	Alt ref rate during temp cntl – 2	TLM	sec	F
DREF(1)	Drag ref during temp cntl – 1	TLM	ND	F
DREF(2)	Drag ref during temp cntl – 2	TLM	ND	F
DRF	Test value during temp cntl	TLM	ND	F

Table 4.5.2.8-2. EGREF I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0430C	VB1	Temperature control – equilibrium glide phase boundary velocity		ft/sec	MX
V97U0421C	VA	Velocity for temperature quadratic where $dD/dV = 0$		ft/sec	MX
V97U0428C	VA1	Boundary velocity between quadratic segments in temperature control phase		ft/sec	MX
V97U0259C	GS1	Factor used in roll command smoothing logic		sec ⁻¹	MX
V97U0260C	GS2	Factor used in roll command smoothing logic		sec ⁻¹	MX
V97U0261C	GS3	Factor used in roll command smoothing logic		sec ⁻¹	MX

4.5.2.9 Entry Guidance Constant Drag Phase (EGREF4).

This function computes the reference values of drag acceleration, altitude rate, and the derivative of range with respect to drag for the constant drag phase.

A. Detailed Requirements. The detailed computations of EGREF4 are:

$$DREFP = T2$$

$$C2 = 0.$$

$$RDTREF = -2. HS T2/VE$$

$$DRDD = -(TRANGE - RPT)/T2$$

The transition initialization flag, ITRAN, is then set to 'ON'.

B. Interface Requirements. The input/output parameters for EGREF4 are listed in Table 4.5.2.9-1. There are no I-Loads/constants for EGREF4.

C. Processing Requirements. EGREF4 is processed at the entry guidance rate when ISLECT = 4.

D. Initialization Requirements. None.

E. Supplemental Information. EGREF4 contains no low energy logic dependencies since initiation of the constant drag phase requires a drag level indicative of a nominal or high energy trajectory.

Table 4.5.2.9-1. EGREF4 Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
T2	Constant drag level to reach target	EGCOMN	ft/sec ²	F
HS	Atmospheric density scale height	EGSCALEHT	ft	F
VE	Ground relative velocity magnitude	NAV	ft/sec	F
TRANGE	Range to runway threshold	NAV	nmi	F
RPT	Desired range at VQ	EGINIT	nmi	F
OUTPUTS				
DREFP	Drag reference used in controller	ENT DIP, TLM, EGTRAN, EGALPCMD, EGLODVCMD, EGGNSLCT, EGEXEC	ft/sec ²	F
C2	Component of (L/D) ref used in controller	EGLODVCMD, TLM	sec ⁻¹	F
RDTREF	Altitude rate reference	EGCOMN, EGLODVCMD	ft/sec	F
ITRAN	Initialization flag for transition phase	EGTRAN	ND	D
DRDD	Derivative of range with respect to drag	ENT DIP, TLM	<u>nmi</u> ft/sec ²	F

4.5.2.10 Entry Guidance Transition Phase (EGTRAN).

The purpose of function EGTRAN is to provide the range predictions and the controller reference quantities during the transition phase.

A. Detailed Requirements. The transition phase computes the range potential from the drag reference level at the end of the constant drag phase to the transition end target conditions, DF and EEF4, and then computes the correct drag–energy profile to null any range error. EGTRAN also computes the controller reference parameters for the bank angle command equation.

On the first pass through the transition phase, and if ITRAN = ‘OFF,’ DREFP is set equal to ALFM and ITRAN is set to ‘ON.’ This provides the ISLECT = 1 to ISLECT = 5 transfer initialization requirement for DREFP. DREFP should be limited so that it cannot be negative or equal to DF. This is required because of the LOG function used in the range prediction equation. This limiting can be accomplished by means of the following equations:

If $(DF + E1) > DREFP > (DF - E1)$, then $DREFP = DF + E1 \text{ SIGN}(DREFP - DF)$

If $DREFP < E1$, then $DREFP = E1$ (Currently, $E1 = 0.01$.)

Next, the slope of the drag energy profile is computed as

$$C1 = \frac{(DREFP - DF)}{(EEF - EEF4)}$$

and the predicted range becomes: $RER1 = -NAUTMI_PER_FT \text{ LOG}(DF/DREFP)/C1$

To correct for the range error, the drag reference (DREFP) is updated through use of an analytic partial derivative of range with respect to drag as follows:

The analytic partial derivative of range with respect to drag is computed and then limited such that its value will always be less than or equal to a maximum value (DRDDL).

$$\begin{aligned} DRDD &= \partial(RER1)/\partial(DREFP) \\ &= NAUTMI_PER_FT/(C1 DREFP) - RER1/(DREFP - DF) \\ DRDD &= \text{MIN}(\text{SCALAR}(DRDD), DRDDL) \end{aligned}$$

DREFP is then updated and is checked to ensure that it maintains a positive value yet does not exceed the maximum drag level (DLIM) representative of control system hinge moment limits. Additionally, if the value of DREFP is found to exceed DLIM, the slope of the drag energy profile (C1) is set to zero. Note: TRNGLE rather than TRANGE will be utilized in the DREFP update equation if the low–energy logic is engaged.

If ICNTAL = OFF,

then $DREFP = DREFP + (TRANGE - RER1 - RPT1) / DRDD$

else $DREFP = DREFP + (TRNGLE - RER1 - RPT1) / DRDD$

$DLIM = ALIM \text{ DRAG}/XLFAC$

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If DREFP > DLIM, then DREFP = DLIM and C1 = 0.0

else If DREFP < E1, then DREFP = E1

The altitude rate reference as well as the L/D reference component (C2) used in the EGLODVCMD controller equation are then computed.

$$RDTREF = -HS \text{ VE} (2. \text{ DREFP} - \text{ C1 VE}^2)/\text{CAG}$$

$$\text{C2} = 4. \text{ VE} \text{ DREFP} (1. - (\text{VE}^2/\text{CAG})^2)/\text{CAG}$$

Finally, an equilibrium glide, vertical lift acceleration for the transition phase is then computed.

$$\text{T1} = \text{GO} (\text{VE}^2 / \text{VSAT2} - 1.)$$

This completes the processing requirements for EGTRAN.

B. Interface Requirements. The input/output parameters for EGTRAN are listed in Table 4.5.2.10-1. The I-loads/constants are listed in Table 4.5.2.10-2.

C. Processing Requirements. EGTRAN is executed at the entry guidance rate when ISLECT = 5.

D. Initialization Requirements. None.

Table 4.5.2.10-1. EGTRAN Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
ITRAN	Initialization flag for transition phase	EGINIT, EGREF, EGREF4	ND	D
DREFP	Drag reference used in controller	EGREF, EGREF4	ft/sec ²	F
EEF	Current energy/mass	EGCOMN	ft ² /sec ²	F
TRANGE	Range to the runway threshold	NAV	nmi	F
HS	Atmospheric density scale height	EGSCALEHT	ft	F
VE2	VE ²	EGCOMN	ft ² /sec ²	F
CAG	Pseudo energy/mass used in transition (L/D) reference	EGCOMN	ft ² /sec ²	F
VSAT2	VSAT ²	EGINIT	ft ² /sec ²	F
VE	Ground relative velocity magnitude	NAV	ft/sec	F
DRAG	Vehicle drag acceleration	NAV	ft/sec ²	F
XLFAC	Total sensed body acceleration	NAV	ft/sec ²	F
ICNTAL	Low-energy logic engagement discrete	EGEXEC, EGROLCMD	ND	D
TRNGLE	Low-energy logic: biased range to the runway threshold	EGEXEC	nmi	F
OUTPUTS				
DREFP	Drag reference used in controller	ENT DIP, TLM, EGEXEC, EGLODVCMD, EGGNSLCT, EGALPCMD	ft/sec ²	F
DRDD	Derivative of range with respect to drag	ENT DIP, TLM	$\frac{\text{nmi}}{\text{ft/sec}^2}$	F
RDTRF	Altitude rate reference	EGCOMN, EGLODVCMD	ft/sec	F
C2	Component of (L/D) ref used in controller	EGLODVCMD, TLM	sec ⁻¹	F
T1	Vertical lift acceleration for equilibrium glide	EGLODVCMD	ft/sec ²	F

Table 4.5.2.10-2. EGTRAN I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0009C	ALFM	Desired constant drag level		ft/sec ²	MX
V97U0121C	DF	Final drag level in transition		ft/sec ²	MX
V97U0228C	E1	Minimum value of DREFP	0.01	ft/sec ²	K
V97U0160C	EEF4	Final reference energy level in transition		ft ² /sec ²	MX
V97U5423C	NAUTMI _PER_FT	Conversion factor from feet to nautical miles	1.6457884E-4	nmi/ft	X
V97U0392C	RPT1	Range bias term		nmi	MX
V97U0010C	ALIM	Maximum sensed acceleration in transition		ft/sec ²	SX
V97U0128C	DRDDL	Minimum value for DRDD		nmi- sec ² /ft	SX
V90A7622C	GO	Earth gravitational acceleration constant	32.174049	ft/sec ²	X

4.5.2.11 Entry Guidance Angle-of-Attack Command (EGALPCMD).

The EGALPCMD function will cyclically (i.e., on each entry guidance execution cycle) initialize the FCS angle-of-attack command (ALPCMD) to the current, relative velocity dependent, nominal angle-of-attack command reference schedule. This ALPCMD update will then be directly used to update the nominal reference angle-of-attack output to displays (ACMD1). Note, once alpha modulation processing has commenced or if contingency low energy operations are in effect, the entry guidance ALPCMD output to the FCS will be reset as appropriate to satisfy these entry guidance operational requirements (ref: entry guidance EGROLCMD function).

A. Detailed Requirements. The angle-of-attack profile commanded by the entry guidance is nominally derived from or constrained by a preselected profile established by means of mission-dependent constants. The entry velocity regime is divided into NALP + 1 segments, and the angle-of-attack command / reference in each segment is defined by a quadratic function of relative velocity.

Upon entry into EGALPCMD, the proper velocity segment for generating the alpha command/reference is found by the following logic:

Do while VE < VALP(IALP)
and IALP > 0:

IALP = IALP - 1

The NALP velocities, VALP(IALP), define the boundaries of the NALP + 1 velocity segments. The counter IALP is saved to minimize the search time on the next guidance pass, and it will be initialized to NALP by the EGINIT function upon initial Entry guidance execution.

The nominal angle-of-attack command, the rate of change of ALPCMD, and the angle-of-attack nominal command reference are computed by:

$$J = IALP + 1$$

$$ALPCMD = CALP0(J) + VE (CALP1(J) + CALP2(J) VE)$$

$$ALPDOT = (ALPCMD - ACMD1)/DTEGD$$

$$ACMD1 = ALPCMD$$

where the constants CALP0(J), CALP1(J), and CALP2(J) (J = 1 to NALP + 1) define the quadratic alpha-velocity profile in each velocity segment.

If the transoceanic abort mode is in effect (ITAL > 0), an entry guidance TAL reconfiguration is performed including the computation of the angle-of-attack coefficients for the angle-of-attack ramp to the nominal profile. These calculations are performed, necessarily only once, as soon as entry guidance closed-loop operations have commenced (ISLECT > 1) and the sensed drag level is greater than a biased reference drag value, as follows:

If (ISLECT > 1 and DRAG > (DREFP + DRFPB) and ITAL = ON and ITAL1 = OFF), then first initialize or reset the indicated parameters as required to enable the entry guidance TAL reconfiguration.

$$ITAL1 = 1$$

$$\text{VALP}(12) = \text{VE}$$

$$\text{VALP}(11) = \text{VE} - \text{VALPD2}$$

$$\text{VALP}(10) = \text{VE} - \text{VALPD1}$$

$$\text{VDEL1} = \text{VALP}(12) - \text{VALP}(10)$$

$$\text{VDEL2} = \text{VALP}(12) - \text{VALP}(11)$$

$$\text{VDEL3} = \text{VALP}(11) - \text{VALP}(10)$$

$$\text{VNOALP} = \text{VE} - \text{VALPD3}(1) - \text{VI} (\text{VALPD3}(2) + \text{VI} (\text{VALPD3}(3) + \text{VI} \text{VALPD3}(4)))$$

$$\text{VYLMAX} = \text{VNOALP}$$

$$\text{VC16} = \text{VNOALP}$$

$$\text{VRDT} = \text{VNOALP}$$

$$\text{NTAL} = \text{NALP2}$$

Next, the TAL α (angle of attack) and $\dot{\alpha}$ points at the intersection with the nominal entry α profile are then determined. Do while $\text{VALP}(10) < \text{VALP}(\text{NTAL})$ and $\text{NTAL} > 0$:

$$\text{NTAL} = \text{NTAL} - 1$$

$$\text{ALP3} = \text{CALP0}(\text{NTAL} + 1) + \text{VALP}(10) (\text{CALP1}(\text{NTAL} + 1) + \text{CALP2}(\text{NTAL} + 1) \text{VALP}(10))$$

$$\text{ALPDT3} = \text{CALP1}(\text{NTAL} + 1) + 2. \text{CALP2}(\text{NTAL} + 1) \text{VALP}(10)$$

Finally, the TAL α ramp quadratic coefficients are determined:

$$\text{CALP2}(11) = \frac{-(\text{ALP3} - \text{ALPCMD} + \text{ALPDT3} (\text{VDEL3} + 0.5 \text{VDEL2}))}{\text{VDEL3} \text{VDEL1}}$$

$$\text{CALP1}(11) = \text{ALPDT3} - 2. \text{CALP2}(11) \text{VALP}(10)$$

$$\text{CALP0}(11) = \text{ALP3} - \text{VALP}(10) (\text{CALP1}(11) + \text{CALP2}(11) \text{VALP}(10))$$

$$\text{CALP2}(12) = \frac{-[\text{ALPDT3} + 2. \text{CALP2}(11) \text{VDEL3}]}{2. \text{VDEL2}}$$

$$\text{CALP1}(12) = -2. \text{CALP2}(12) \text{VALP}(12)$$

$$\text{CALP0}(12) = \text{ALPCMD} - \text{VALP}(12) (\text{CALP1}(12) + \text{CALP2}(12) \text{VALP}(12))$$

This completes the processing requirements for EGALPCMD.

B. Interface Requirements. The input/output parameters for EGALPCMD are listed in Table 4.5.2.11-1. The I-loads used are listed in Table 4.5.2.11-2.

C. Processing Requirements. EGALPCMD is processed at the entry guidance rate during the entire entry major mode.

D. Initialization Requirements. The counter IALP is set to NALP in EGINIT before the first entry into EGALPCMD.

Table 4.5.2.11-1. EGALPCMD Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
VI	Vehicle inertial speed	NAV	ft/sec	F
IALP	ALPCMD segment counter	EGINIT	ND	I
ISLECT	Guidance phase counter	EGEXEC	ND	I
DRAG	Drag acceleration	NAV	ft/sec ²	F
DREFP	Drag reference	EGREF, EGREF4, EGTRAN	ft/sec ²	F
ITAL	TAL abort discrete	MSC	ND	D
ITAL1	TAL abort first-pass flag	EGINIT	ND	D
OUTPUTS				
ACMD1	Nominal angle of attack command reference (i.e., scheduled angle of attack)	EGROLCMD, ENT DIP	deg	F
ALPCMD	Angle-of-attack command	AEROJET DAP, TLM, EGLODVCMD	deg	F
ALPDOT	Rate of change of ALPCMD	EGLODVCMD	deg/sec	F
VC16	Velocity to enable drag bias term	EGGNSLCT	ft/sec	F
VRDT	Velocity to initiate \dot{h} correction processing	EGLODVCMD	ft/sec	F
VNOALP	α modulation velocity constraint	EGLODVCMD, EGROLCMD	ft/sec	F
VYLMAX	Velocity for ALMN4 limit	EGLODVCMD	ft/sec	F

Table 4.5.2.11-2. EGALPCMD I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0422C	VALP(1)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0423C	VALP(2)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0424C	VALP(3)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0425C	VALP(4)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0426C	VALP(5)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0427C	VALP(6)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0488C	VALP(7)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0489C	VALP(8)	ALPCMD versus VE segment boundary		ft/sec	MX
V97U0490C	VALP(9)	ALPCMD versus VE segment boundary		ft/sec	MX
V99U7394C	VALP(10)	ALPCMD versus VE segment boundary		ft/sec	MX
V99U7395C	VALP(11)	ALPCMD versus VE segment boundary		ft/sec	MX
V99U7396C	VALP(12)	ALPCMD versus VE segment boundary		ft/sec	MX
V99U7398C	VALPD1	TAL pitchdown velocity segment		ft/sec	MX
V99U7399C	VALPD2	TAL pitchdown mid-velocity segment		ft/sec	MX
V99U6981C	VALPD3(1)	VNOALP constant term for TAL		ft/sec	MX
V99U6982C	VALPD3(2)	VNOALP slope wrt VI for TAL		ND	MX
V99U6983C	VALPD3(3)	VNOALP quadratic term in VI		sec/ft	MX
V99U6984C	VALPD3(4)	VNOALP cubic term in VI for TAL		sec ² /ft ²	MX
V97U0043C	CALP0(1)	ALPCMD constant term		deg	MX
V97U0044C	CALP0(2)	ALPCMD constant term		deg	MX
V97U0045C	CALP0(3)	ALPCMD constant term		deg	MX
V97U0046C	CALP0(4)	ALPCMD constant term		deg	MX
V97U0047C	CALP0(5)	ALPCMD constant term		deg	MX
V97U0048C	CALP0(6)	ALPCMD constant term		deg	MX
V97U0049C	CALP0(7)	ALPCMD constant term		deg	MX
V97U0479C	CALP0(8)	ALPCMD constant term		deg	MX
V97U0480C	CALP0(9)	ALPCMD constant term		deg	MX
V97U0481C	CALP0(10)	ALPCMD constant term		deg	MX
V99U7385C	CALP0(11)	ALPCMD constant term		deg	MX
V99U7386C	CALP0(12)	ALPCMD constant term		deg	MX
V99U7387C	CALP0(13)	ALPCMD constant term		deg	MX
V97U0050C	CALP1(1)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0051C	CALP1(2)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0052C	CALP1(3)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0053C	CALP1(4)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0054C	CALP1(5)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0055C	CALP1(6)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0056C	CALP1(7)	ALPCMD slope with respect to VE		deg-sec/ft	MX

Table 4.5.2.11-2. EGALPCMD I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0482C	CALP1(8)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0483C	CALP1(9)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V97U0484C	CALP1(10)	ALPCMD slope with respect to VE		deg-sec/ft	MX
V99U7388C	CALP1(11)	ALPCMD slope wrt VE		deg-sec/ft	MX
V99U7389C	CALP1(12)	ALPCMD slope wrt VE		deg-sec/ft	MX
V99U7390C	CALP1(13)	ALPCMD slope wrt VE		deg-sec/ft	MX
V97U0057C	CALP2(1)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0058C	CALP2(2)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0059C	CALP2(3)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0060C	CALP2(4)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0061C	CALP2(5)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0062C	CALP2(6)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0063C	CALP2(7)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0485C	CALP2(8)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0486C	CALP2(9)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V97U0487C	CALP2(10)	ALPCMD quadratic term in VE		deg-sec ² /ft ²	MX
V99U7391C	CALP2(11)	ALPCMD quadratic term in VE		deg-sec ² /ft	MX
V99U7392C	CALP2(12)	ALPCMD quadratic term in VE		deg-sec ² /ft	MX
V99U7393C	CALP2(13)	ALPCMD quadratic term in VE		deg-sec ² /ft	MX
V99U7403C	NALP2	NTAL initialization value		ND	MX
V97U6100C	DTEGD	Entry guidance cycle interval	1.92	sec	X
V99U7397C	DRFPB	Drag bias for TAL α profile ramp		ft/sec ²	MX

4.5.2.12 Entry Guidance Gain Selection (EGGNSLCT).

The purpose of EGGNSLCT is to generate the controller gains C16 and C17 for the vertical L/D command required in the roll command equation.

A. Detailed Requirements. The entry guidance requires a vertical L/D command required to drive the actual trajectory to the desired drag profile. The vertical L/D command equation is computed in EGLODVCMD and has the form

$$\left(\frac{L_v}{D}\right)_{\text{command}} = \left(\frac{L_v}{D}\right)_{\text{ref}} + C16 (D - DREFP) - C17 (\dot{R} - RDTREF)$$

The gains C16 and C17 are shaped (as a function of the vehicle's sensed drag) to drive the orbiter to the reference drag level (DREFP) with a desired frequency and damping ratio. Figure 4.5.2.12-1 shows representative gain schedules.

The gain schedule for C16 versus drag yields the following C16 update equation:

$$C16 = CT16(1) DRAG^{CT16(2)}$$

If the current velocity is less than VC16, a drag bias term is added to C16 to improve roll reversal phugoid damping at high drag acceleration levels through use of the calculated drag error as follows:

$$DD = DRAG - DREFP$$

$$\text{If } VE < VC16, \text{ then } C16 = C16 + CT16(3) DD$$

C16 is then always limited such that $CT16MN \leq C16 \leq CT16MX$.

In a similar manner

$$C17 = CT17(1) DRAG^{CT17(2)}$$

If the α modulation flag, ICT, is set to 1, the value of CT17MN is reset to CT17M2 by:

$$\text{If } ICT = 1, \text{ then } CT17MN = CT17M2$$

C17 is then always limited such that $CT17MN \leq C17 \leq CT17MX$. Finally, if $ICT = 1$, the limited value of C17 is reset as follows:

$$\text{If } ICT = 1, \text{ then } C17 = C17MP \quad C17$$

B. Interface Requirements. The input and output parameters for EGGNSLCT are listed in Table 4.5.2.12-1. The I-loads for EGGNSLCT are listed in Table 4.5.2.12-2.

C. Processing Requirements. EGGNSLCT is processed at the entry guidance rate before EGLODVCMD when ISLECT > 1.

D. Initialization Requirements. None.

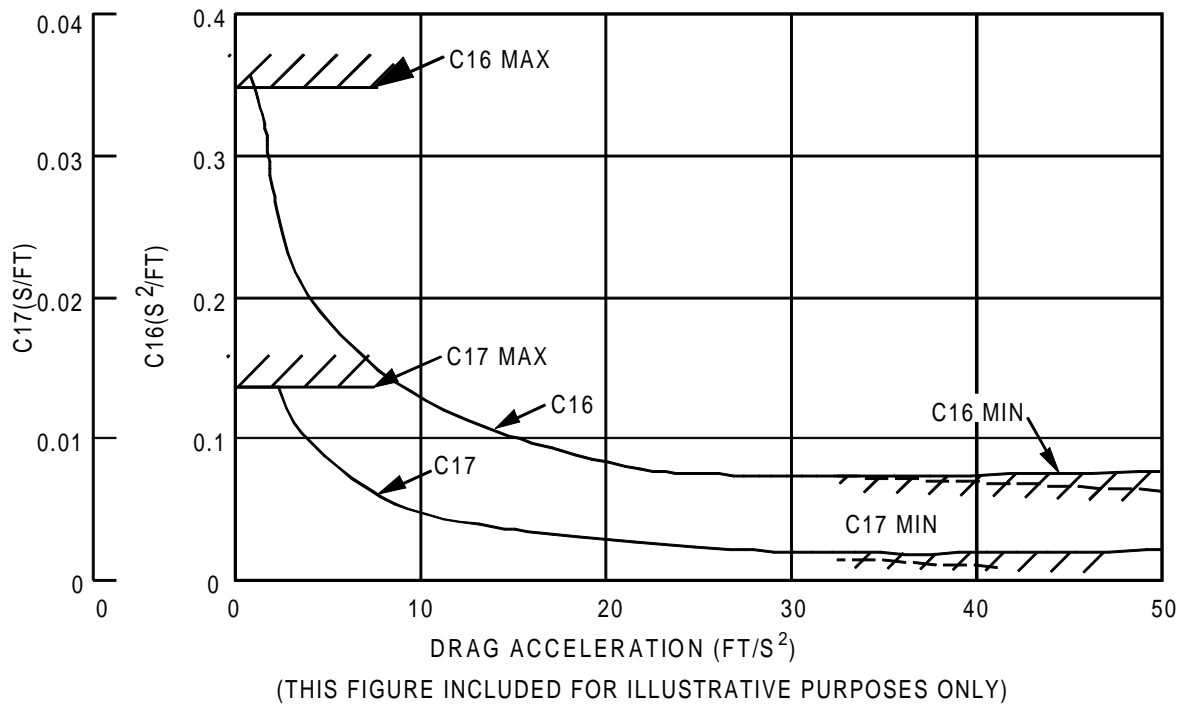


FIGURE 4.5.2.12-1. Entry Controller Gain Schedule

Table 4.5.2.12-1. EGGNSLCT Input/Output Variables				
Name	Description	Source / Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
DRAG	Current drag acceleration	NAV	ft/sec ²	F
DREFP	Drag reference used in controller	EGREF, EGREF4, EGTRAN	ft/sec ²	F
ICT	Alpha modulation flag	EGLODVCMD, EGINIT	ND	I
VC16	Velocity to enable drag bias term	EGINIT, EGALPCMD	ft/sec	F
OUTPUTS				
C16	d(L/D)/dD used in controller	EGLODVCMD, TLM	sec ² /ft	F
C17	d(L/D)/d \dot{H} used in controller	EGLODVCMD, TLM	sec/ft	F
DD	Drag error	EGLODVCMD, EGROLCMD	ft/sec ²	F

Table 4.5.2.12-2. EGGNSLCT I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0078C	CT16(1)	C16 coefficient		sec ² /ft ²	SX
V97U0079C	CT16(2)	C16 power coefficient		ND	SX
V97U0080C	CT16(3)	C16 drag bias coefficient		sec ⁴ /ft ²	SX
V97U0083C	CT17(1)	C17 coefficient		sec/ft	SX
V97U0084C	CT17(2)	C17 power coefficient		ND	SX
V97U0081C	CT16MN	Minimum value of C16		sec ² /ft	SX
V97U0082C	CT16MX	Maximum value of C16		sec ² /ft	SX
V97U0085C	CT17MN	Minimum value of C17		sec/ft	SX
V97U0086C	CT17MX	Maximum value of C17		sec/ft	SX
V97U0432C	VC16	Velocity to enable drag bias term		ft/sec	SX
V97U0502C	C17MP	Multiplication factor on C17 when ICT = 1		ND	SX
V97U0503C	CT17M2	Value of CT17MN when ICT = 1		sec/ft	SX

4.5.2.13 Entry Guidance Lateral Logic and Vertical L/D Command (EGLODVCMD).

The purpose of EGLODVCMD is to generate vertical L/D commands for the roll-angle command equations and to determine the sign for the roll command in order to null the cross range error.

A. Detailed Requirements. In order to null the downrange and cross range errors, the guidance must generate a roll-angle command and a roll direction. The magnitude of the roll command is based on converging the actual trajectory to the reference drag profile required for ranging. This roll command is based on a vertical L/D command (LODV) computed from the following equations:

$$LODX = ALDREF + C16 \text{ DD} + C17 (\text{RDTRF} + \text{DLRDOT} - \text{RDOT})$$

$$LODV = LODX$$

In EGROLCMD, LODX will be used to calculate an unlimited roll command and LODV will be used to calculate the roll command sent to the FCS and displays. The error correction coefficients C16 and C17 are computed in EGGNSLCT, Section 4.5.2.12.

Before LODV is computed, the L/D reference (ALDREF) is computed and the altitude rate reference (RDTREF) is corrected for the time rate of change of drag coefficient, \dot{C}_d .

$$ALDREF = -T1/DREFP + (2 \cdot \text{RDTREF} + C2 \text{ HS})/VE$$

The derivative \dot{C}_d affects RDTREF as follows: Differentiating the basic drag formula

$$D = C_d \rho V_E^2 S g/(2W)$$

$$\text{yields } \dot{h} = h_s \left(\frac{2\dot{V}_E}{V_E} - \frac{\dot{D}}{D} + \frac{\dot{C}_d}{C_d} \right)$$

where $D = DREFP$. The RDTREF or altitude rate reference as input to EGLODVCMD has yet to account for this $h_s \dot{C}_d/C_d$ term. This term is now obtained through a best-fit approximation for C_d (as a function of α and V_E) and for \dot{C}_d (as a function of α , $\dot{\alpha}$, and V_E) as follows:

$$CDCAL = C_d = CDDOT4 + ALPCMD (CDDOT5 + CDDOT6 \text{ ALPCMD}) + CDDOT3 \text{ A44}$$

$$\text{where } A44 = e^{-\left(\frac{VE - CDDOT1}{CDDOT2}\right)}$$

$$\begin{aligned} CDDOTC &= \dot{C}_d = CDDOT7 (\text{DRAG} + \text{GO} \text{ RDOT}/VE) \text{ A44} \\ &+ \text{ALPDOT} (CDDOT8 \text{ ALPCMD} + CDDOT9) \end{aligned}$$

$$C4 = \text{HS} \text{ CDDOTC}/CDCAL$$

The corrected altitude rate reference is then computed.

$$\text{RDTRF} = \text{RDTREF} + C4$$

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A velocity check is then performed to determine if angle-of-attack modulation should be initiated in order to facilitate convergence of the actual vs. reference drag profiles. If $VE < VNOALP$, then determine the status for alpha modulation processing (as indicated by the alpha modulation flag, ICT, where $ICT = 1$ denotes alpha modulation processing has commenced) as follows:

If $DRAG \geq DREFP$ or if $VE < VALMOD$ or if $ICT = 1$: then ICT is set to 1; the $\partial C_d / \partial \alpha$ gain, C20, is computed; and the delta alpha command increment, DELALP, is processed. Note, whenever alpha modulation processing is in effect (i.e., $ICT = 1$), the delta alpha command increment will be set to zero if the magnitude of the drag error, DD, is less than some minimum value (DDMIN).

$$C20 = MIDVAL(C21, C22 + C23 VE, C24)$$

$$\text{If } VE < VC20, \text{ then } C20 = MAX(SCALAR(C25 + C26 VE, C27))$$

$$DELALP = MIDVAL(CDCAL ((DREFP / DRAG) - 1.) / C20, DLAPLM, -DLAPLM)$$

$$\text{If } ABS(DD) < DDMIN, \text{ then } DELALP = 0.0$$

Because of the possibility of large altitude rate errors in the \dot{h} input from navigation, a correction to the altitude rate reference is made based on a feedback on the $DRAG - DREFP$ error. The following logic is used to calculate this correction term:

If $VE < VRDT$, calculate the following:

1. A limited drag error based on the I-load value, DDLIM.

$$DDS = MIDVAL(DD, -DDLIM, DDLIM)$$

2. The \dot{h} feedback gain, ZK, is set to the I-load value ZK1.

$$ZK = ZK1$$

3. A check is made to see if a roll reversal has been initiated. If true, an \dot{h} feedback lockout velocity, VTRB, is calculated; a second lockout velocity, VTRB1, is computed for the auto PTI constraints; and the auto PTI deadband selection counter is incremented by one as follows:

If $(RK2ROL \text{ } RK2RLP < 0)$, then

$$VTRB = VE - ACN1 DREFP$$

$$VTRB1 = VE - ACN2 DREFP$$

$$DYLN = DYLN + 1$$

4. If the drag error is converging, or if the \dot{h} feedback lockout velocity is exceeded or if the roll command is saturated, the \dot{h} feedback is held constant by setting ZK, the \dot{h} feedback gain, to zero.

If $(ABS(DD) \leq ABS(DDP) \text{ or } VE > VTRB \text{ or } LMFLG > 0)$, then $ZK = 0$.

5. The auto PTI acceptable discrete is set false if the auto PTI lockout velocity is exceeded.

If $VE > VTRB1$, then $GUID_ACCEP = FALSE$.

6. The \dot{h} correction term is then computed by

$$DLRDOT = MIDVAL(DLRDOT + ZK DDS, DLRDTM, -DLRDTM)$$

7. As the \dot{h} correction term is effectively an integrator function, there is the intrinsic potential for an undesirable “bias” to accrue which may be degradative to attainment of the desired drag profile required to satisfy ranging requirements. Given this possibility, a capability exists which allows the crew to “zero out” this correction term via a display item entry. In order to respond to this optional crew “command”, an entry guidance test for the “zero \dot{h} bias command” (DLRDTZ) is performed. If DLRDTZ is “ON”, the altitude rate correction term is set to zero and the crew input command is set to “OFF” as follows:

If $DLRDTZ = ON$, then $DLRDOT = 0.0$ and $DLRDTZ = OFF$

Finally, following completion of the above equation sets as dependent on the logical test on $VE < VRDT$, the values of DD and RK2ROL are saved in DDP and RK2RLP, respectively.

$$DDP = DD$$

$$RK2RLP = RK2ROL$$

LODX and LODV are then calculated using the equations given previously.

The other output of EGLODVCMD is the roll angle command direction, RK2ROL. The roll direction is reversed when the velocity heading error with respect to HAC tangency, DELAZ, exceeds a heading error deadband, YL, and the current bank direction is increasing the heading error with time. The heading error deadband is computed by

$$YL = CYO + CY1 VE$$

and then limited so that

$$Y2 \leq YL \leq Y1$$

A representative heading error deadband is shown in Figure 4.5.2.13-1. The heading error limit for the auto PTI acceptable discrete is computed by $YL1 = YL - DYL$.

A need for ensuring positive crossrange control is indicated when the heading error (DELAZ) and the vehicle’s roll attitude are of opposite sign. Under these conditions, the computed vertical L/D (LODV) required to achieve or maintain the desired drag profile will be limited to be no greater than a determined maximum value (LMN) which will effectively provide a minimum limit on the roll command magnitude. The process for determining LMN is as follows:

- 1.1 LMN is first set to the value of ALMN2.

$$LMN = ALMN2$$

1.2 The sign of the rate of change for the heading error is then determined.

$$DZSGN = ABS(DELAZ) - ABS(DZOLD)$$

$$DZOLD = DELAZ$$

1.3 A hysteresis deadband dependent on the sign for the rate of change of heading error (DZSGN) and heading error limits is then checked for resetting LMN if required.

$$\text{If } DZSGN > 0. \text{ and } (YL - YLMIN) < ABS(DELAZ)$$

or

$$\text{If } DZSGN \leq 0. \text{ and } (YL - YLMN2) < ABS(DELAZ),$$

$$\text{then } LMN = ALMN1$$

1.4 If the low-energy logic engagement discrete is set, the following logic is exercised for determination of the low-energy logic roll command:

If ICNTAL = ON, then Equation A is executed.

$$\text{A.0 If } VE \geq VTURN \text{ or } (DZSGN > 0.0 \text{ and } ABS(DELAZ) \leq DLZDB1) \\ \text{or } (DZSGN \leq 0.0 \text{ and } ABS(DELAZ) \leq DLZDB2),$$

$$\text{then } ROLLMN = 0.0$$

else execute Equation Set B.

$$\text{B.1 } RK2ROL = - SIGN(DELAZ)$$

$$\text{B.2 If } DZFCTR \text{ ABS(DELAZ) DEG_PER_RAD} < ROLMN2 \\ \text{and } DREFP \geq (BEQGLM - DXRCHK) \\ \text{and } ABS(DELAZ) \geq DLZLM1 \text{ and } DZSGN > 0.0, \\ \text{then } DZFCTR = DZFCTR (1.0 + DZFDEL)$$

$$\text{B.3 If } ABS(DELAZ) < DLZLM2 \text{ and } DZSGN < 0.0, \\ \text{then } DZFCTR = MAX[DLZFAC, DZFCTR (1.0 - DZFDEL)]$$

$$\text{B.4 } ROLLMN = RK2ROL \text{ MIDVAL}(ROLMN1, \\ DZFCTR \text{ ABS(DELAZ) DEG_PER_RAD}, ROLMN2)$$

- 1.5 Velocity dependent, LMN constraints are now applied. Additionally, the sign for the roll command(s), RK2ROL, will be updated per velocity and FCS lateral mode dependencies.

If $VE > VYLMAX$,

then $LMN = ALMN4$

else execute Equation Set C.

C.1 If $VE < VELMN$, then $LMN = ALMN3$

C.2 If $AUTORY_LAMP = OFF$, then $RK2ROL = SIGN(ROLL)$

- 1.6 The LMN value to be used for crossrange dependent, roll command limiting as well as the LMN crossrange constraint parameter (DLZRL) are now determined. If the first roll reversal has occurred, the heading error deadband limit, Y1, will also be updated.

$LMN = LMN\ XLOD$

$DLZRL = DELAZ\ RK2ROL$

If $RK2ROL\ RK2RLP > 0$. and $IDBCHG = ON$, then $Y1 = Y3$

The remainder of EGLOBALVCMD involves the use of LMN for LODV limiting if required for crossrange control, the determination for a roll reversal requirement, and the processing of other heading error or roll reversal dependent calculations as related to auto PTI inhibits, the TAL alpha modulation capability, and the low-energy logic engagement status. These requirements are described by the following:

If $ABS(LODV) < LMN$ or $DLZRL > 0.0$ or $ICNTAL = ON$, then perform the following:

- 2.1 The roll saturation flag (LMFLG) is set to zero and LMN is reset to the current L/D (XL0D).

$LMFLG = 0$

$LMN = XL0D$

- 2.2 The auto PTI acceptance flag is set to false if the PTI heading error constraint is exceeded.

If $DLZRL \geq YL1$, then $GUID_ACCEP = FALSE$.

- 2.3 A heading error test is then made for determining the need for a roll reversal. If this test is satisfied, the sign for RK2ROL is reversed, the heading error deadband limit selection flag is set to ON, and the auto PTI heading error limit is determined as dependent on the auto PTI heading error deadband counter. The TAL alpha modulation constraint velocity is also updated.

If $DLZRL \geq YL$ and $ICNTAL = OFF$, then process Equation Set C.

$$C.1 \text{ RK2ROL} = -\text{RK2ROL}$$

$$C.2 \text{ IDBCHG} = \text{ON}$$

$$C.3 \text{ If } \text{ITAL} = \text{TRUE}, \text{ then } \text{VNOALP} = \text{VNOALP2}$$

$$C.4 \text{ If } \text{DYLN} = 1, \text{ then } \text{DYL} = \text{DYL2}$$

$$C.5 \text{ If } \text{DYLN} = 2, \text{ then } \text{DYL} = \text{DYL3}$$

$$C.6 \text{ If } \text{DYLN} = 3, \text{ then } \text{DYL} = \text{DYL4}$$

If the above $LODV$, $DLZRL$, and $ICNTAL$ test fails, i.e., $ABS(LODV) \geq LMN$ and $DLZRL \leq 0$. and $ICNTAL = OFF$, then the roll saturation flag is set to one and $LODV$ is reset to the value of LMN as follows:

$$\text{LMFLG} = 1$$
$$\text{LODV} = \text{LMN} \text{ SIGN}(\text{LODV})$$

B. Interface Requirements. Table 4.5.2.13–1 presents the $EGLODVCMD$ input and output variables. The I-loads/constants are listed in Table 4.5.2.13–2.

C. Processing Requirements. $EGLODVCMD$ is processed at the entry guidance rate after $EGGNSLCT$ when $ISLECT > 1$.

D. Initialization Requirements. None.

E. Supplemental Information. Theoretically, $RDTREF$ should be corrected for C_d before being used in the $ALDREF$ equation. However, the C_d function could introduce an undesirable roughness in $LODV$. Hence, the uncorrected $RDTREF$ is used in $ALDREF$. $C4$ and $ALDREF$ may be downlink parameters.

Entry guidance $EGLODVCMD$ processing with respect to the heading error limit dependency used for commanding a roll reversal and with respect to the auto PTI deadband heading error limit update contains “quirks” which were introduced in OI–22 (ref: CR 90152D) and have since been documented via DRs for OI–22 and subs. The following is provided to summarize these known problems.

For the roll reversal heading error limit, a condition could arise where if the flight crew should purposely or inadvertently mode to manual roll/yaw operations during the initial half (i.e., prior to rolling through a roll attitude of zero degrees) of the first (and only first) roll reversal, entry guidance will likely “abort” the roll reversal command and resume a roll command sign commensurate with what was being issued prior to this roll reversal event. This “quirk” is due to the heading error deadband limit update (i.e., $Y1 = Y3$) which occurs during auto initiation of the first roll reversal and is premised on a $Y3$ value greater than that initially specified for $Y1$. Given this $Y1 = Y3$ update and an FCS moding to manual roll/yaw (i.e., $AUTORY_LAMP = OFF$), the $RK2ROL$ term will be updated to the sign of the current roll attitude which will induce a sign change for $DLZRL$ (will become positive prior to rolling through wings level), and this $DLZRL$ sign change will reinvoke the roll reversal test dependency specified for processing Equation Set 2. Given an increase in the value for YL due to the $Y1 = Y3$ update, the $DLZRL > YL$ test will likely not be satisfied which will induce a roll command sign reversal due to the $RK2ROL = \text{SIGN}(\text{ROLL})$ manual

roll/yaw dependency if the first roll reversal has not yet maneuvered through wings level. This particular quirk is documented via DR 108586.

The other “anomaly” induced as a “side effect” of CR 90152D is with respect to the auto PTI heading error deadband value update. The following is provided to hopefully better explain the current (OI-22 and subs) mechanism in place for determining the auto PTI DELAZ deadband values. Initially, the auto PTI deadband selection counter, DYLN, is set to zero and the auto PTI DELAZ deadband value, DYL, is set to DYL1. Both of these initializations are performed by the EGINIT function. Subsequently, the PTI deadband counter, DYLN, will only be incremented on the guidance execution cycle following the issuance of a roll reversal command and if the vehicle’s sensed relative velocity is less than the value for VRDT. Specifically, if $VE < VRDT$ and $RK2ROL \cdot RK2RLP < 0$, then $DYLN = DYLN + 1$. Per current requirements, an auto PTI DELAZ deadband update as dependent on a change to the deadband counter, DYLN, can only occur if a roll reversal command is subsequently required (i.e., $DLZRL > YL$ where $DLZRL = DELAZ \cdot RK2ROL$). Since for FCS lateral channel auto mode operations, a change to RK2ROL should only occur on the entry guidance execution cycle which detects the need for a change in the sign for RK2ROL (roll reversal command), the process for updating DYLN after issuance of the roll reversal command will ultimately have no effect until the next roll reversal occurs some, say, five minutes later since the PTI DELAZ deadband selection logic is only exercised when a roll reversal command is required. The net effect for auto mode operations during roll reversals is that the auto PTI DELAZ deadband update is effectively delayed by one roll reversal such that the value of DYL1 will be used prior to and after the first roll reversal, DYL2 will then be in effect after the second reversal, DYL3 will be in effect after the third reversal, etc. Hence, the DYL1, 2, 3 and 4 I-Loads need to reflect DELAZ deadband values appropriate to the expected flight regimes and operating conditions subsequent rather than prior to a given numbered roll reversal. Note, DYL1 is somewhat an exception to this “after roll reversal prescription” in that it is used for the auto PTI deadband constraint both prior to and after the first reversal due to the DYLN counter being initialized to 0. For manually executed roll reversals (i.e., CSS roll/yaw), an alteration to the above will occur in that a logic test is provided to update the value of RK2ROL to reflect the current sign of the roll attitude. This test is performed after the DYLN counter test but prior to the roll reversal (heading error exceedance) test. The end effect is that for a manually initiated and performed roll reversal, the roll reversal command logic including the selection for the PTI DELAZ deadband value will be continually exercised which will induce an immediate update to DYL (rather than be delayed to the next reversal). Due to this manual vs. auto mode processing difference, the I-Load values for DYL1, 2, 3 and 4 must reflect values compatible with whether they are to be utilized prior to or after the corresponding roll reversal number. This auto PTI deadband quirk has been formally documented via DR 108797.

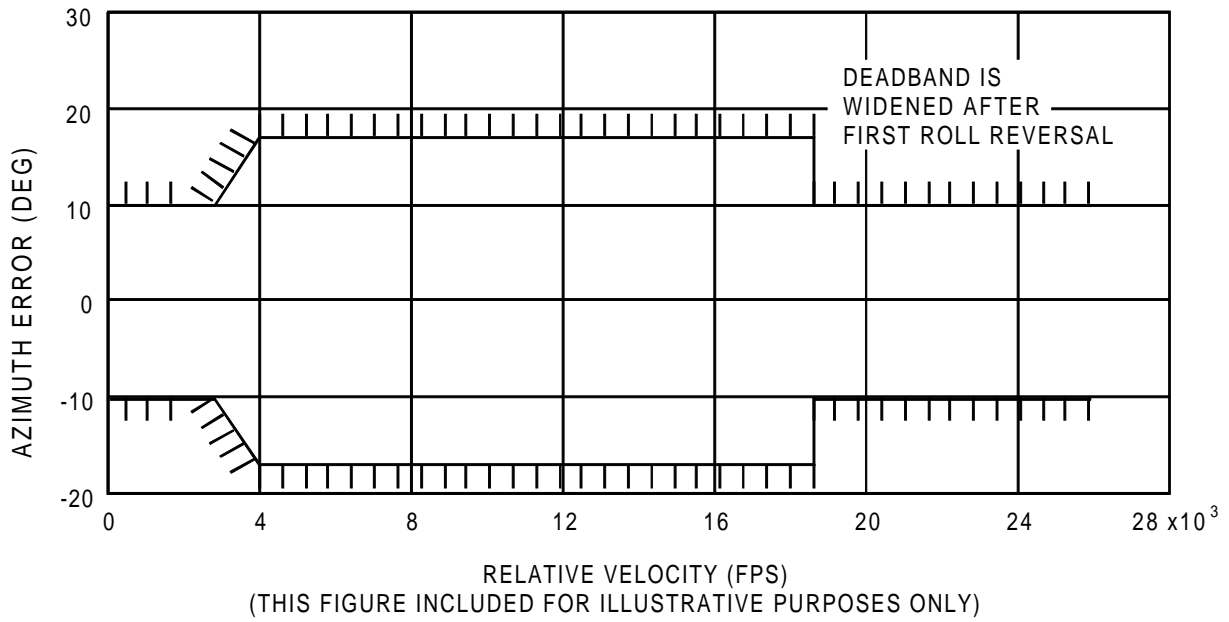


FIGURE 4.5.2.13-1. Lateral Deadband

Table 4.5.2.13-1. EGLODVCMD Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
VE	Ground relative velocity magnitude	NAV	ft/sec	F
RDTREF	Altitude rate reference	EGREF, EGREF4, EGTRAN	ft/sec	F
ISLECT	Guidance phase counter	EGEXEC	ND	I
T1	Vertical lift acceleration for equilibrium glide	EGCOMN, EGTRAN	ft/sec ²	F
C2	Component of ALDREF	EGREF, EGREF4, EGTRAN	sec ⁻¹	F
HS	Atmospheric density scale height	EGSCALEHT	ft	F
C16	d(L/D)/dD used in controller	EGGNSLCT	sec ² /ft	F
C17	d(L/D)/d \dot{h} used in controller	EGGNSLCT	sec/ft	F
DRAG	Current drag acceleration	NAV	ft/sec ²	F
RDOT	Current altitude rate with respect to oblate Earth	NAV	ft/sec	F
ROLL	Body roll attitude	A/E ATT PROC	deg	F
DREFP	Drag reference used in controller	EGREF, EGREF4, EGTRAN	ft/sec ²	F
DELAZ	Orbiter heading deviation from tangency with the selected HAC	NAV	rad	F
XLOD	Limited lift/drag ratio	EGCOMN	ND	F
RK2ROL	Roll direction	EGINIT, EGCOMN	ND	F
RK2RLP	Past value of RK2ROL	EGINIT	ND	F
ALPCMD	Angle-of-attack command	EGALPCMD	deg	F
ALPDOT	Rate of change of ALPCMD	EGALPCMD	deg/sec	F
DZOLD	Previous value of DELAZ	EGINIT	rad	F
DD	Drag error	EGGNSLCT	ft/sec ²	F
DDP	Past value of DD	EGINIT	ft/sec ²	F
DYL	Auto PTI DELAZ deadband	EGINIT	rad	F
ICT	α modulation flag	EGINIT	ND	I
DYLN	Auto PTI DELAZ deadband counter	EGINIT	ND	I
IDBCHG	Lateral deadband Flag	EGINIT	ND	I
DLRDOT	\dot{h} feedback	EGINIT	ft/sec	F
DLRDTZ	\dot{h} feedback zero flag	EGINIT, ENT TRAJ 1-5	ND	D
LMFLG	\dot{h} lockout flag for saturated roll command	EGINIT	ND	I
ITAL	Transoceanic abort discrete	MSC	ND	D

Table 4.5.2.13-1. EGLODVCMD Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
VNOALP	α modulation velocity constraint	EGINIT, EGALPCMD	ft/sec	F
VTRB	\dot{h} feedback velocity lock-out	EGINIT	ft/sec	F
VTRBI	Auto PTI velocity lock-out	EGINIT	ft/sec	F
VYLMAX	Velocity for ALMN4 limit	EGINIT, EGALPCMD	ft/sec	F
VRDT	Velocity to initiate \dot{h} correction processing	EGINIT, EGALPCMD	ft/sec	F
ICNTAL	Low-energy logic engagement discrete	EGEXEC, EGROLCMD	ND	D
AUTORY_ LAMP	Auto status lamp for roll / yaw axis	AEROJET DAP	ND	D
VTURN	Low-energy logic: maximum velocity for nonzero roll commands	EGINIT	ft/sec	F
DZFCTR	Low-energy logic: variable DELAZ factor for roll command computation	EGEXEC	ND	F
BEQGLM	Low-energy logic: biased equilibrium glide boundary	EGROLCMD	ft/sec ²	F
DZFDEL	Low-energy logic: DZFCTR increment / decrement	EGEXEC	ND	F
OUTPUTS				
RK2ROL	Roll direction	EGROLCMD, TLM	ND	F
LODV	Desired vertical L/D ratio	EGROLCMD, TLM	ND	F
RDTRF	Altitude rate reference corrected for \dot{C}_d	ENT TRAJ 1-5, TLM	ft/sec	F
ALDREF	Lift/drag reference	EGROLCMD, TLM	ND	F
LODX	Desired unlimited vertical L/D ratio	EGROLCMD	ND	F
DLRDOT	\dot{h} correction	TLM	ft/sec	F
YL	Max heading error	ENT DIP	rad	F
ICT	α modulation flag	EGGNSLCT, EGROLCMD	ND	I
DELALP	Commanded α increment	EGROLCMD	deg	F
LMN	Vertical L/D cmd for minimum roll angles	EGROLCMD	ND	F
GUID_ ACCEP	Auto PTI acceptable discrete	PTI (AEROJET DAP)	ND	D
ROLLMN	Low-energy logic: roll command	EGROLCMD	deg	F
VNOALP	α modulation velocity constraint	EGROLCMD	ft/sec	F

Table 4.5.2.13-2. EGLODVCMD I -Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0109C	CY0	Constant term in heading error deadband slope		rad	SX
V97U0110C	CY1	Slope of heading error deadband with respect to VE		rad-sec/ft	SX
V97U0467C	Y1	Maximum heading error deadband before first reversal		rad	SX
V97U0468C	Y2	Minimum heading error deadband		rad	SX
V97U0478C	Y3	Maximum heading error deadband after first roll		rad	SX
V97U0011C	ALMN1	Maximum (L/D) command outside of heading error deadband		ND	SX
V97U0012C	ALMN2	Maximum (L/D) command inside of heading error deadband		ND	SX
V97U0013C	ALMN3	Maximum (L/D) command below VELMN		ND	SX
V97U0014C	ALMN4	Maximum (L/D) command above VYLMAX		ND	SX
V97U0477C	DLRDTM	Maximum value of DLRDOT		ft/s	SX
V97U0433C	VELMN	Maximum velocity for using ALMN3 limit		ft/sec	SX
V90A7622C	GO	Earth gravitational acceleration constant	32.174049	ft/sec ²	X
V97U0465C	YLMIN	YL bias used in test for LMN		rad	SX
V97U0466C	YLMN2	YL bias used in test for LMN		rad	SX
V97U0442C	VYLMAX	Velocity for ALMN4 limit		ft/sec	SX
V97U0064C	CDDOT1	CD velocity coefficient		ft/sec	SX
V97U0065C	CDDOT2	CD velocity coefficient		ft/sec	SX
V97U0066C	CDDOT3	CD velocity coefficient		ND	SX
V97U0067C	CDDOT4	CD alpha coefficient		ND	SX
V97U0068C	CDDOT5	CD alpha coefficient		deg ⁻¹	SX
V97U0069C	CDDOT6	CD alpha coefficient		deg ⁻²	SX
V97U0070C	CDDOT7	$\dot{C}D$ coefficient		sec/ft	SX
V97U0071C	CDDOT8	$\dot{C}D$ coefficient		deg ⁻²	SX
V97U0072C	CDDOT9	$\dot{C}D$ coefficient		deg ⁻¹	SX
V97U0006C	ACN1	Time constant for \dot{h} feedback		sec	SX
V97U0111C	DDLIM	Maximum delta drag for \dot{h} feedback		ft/sec ²	SX
V97U0438C	VRDT	Velocity to initiate \dot{h} correction processing		ft/sec	SX
V97U0469C	ZK1	\dot{h} feedback gain		sec	SX
V97U0515C	VNOALP	α modulation velocity constraint		ft/sec	MX
V97U0513C	VALMOD	α modulation initiate velocity for non-convergence of drag to DREFP		ft/sec	MX

Table 4.5.2.13-2. EGLDVCMD I -Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0506C	C21	C20 constant value		deg ⁻¹	MX
V97U0507C	C22	C20 constant value in linear term		deg ⁻¹	MX
V97U0508C	C23	C20 linear term		sec/ft-deg	MX
V97U0509C	C24	C20 constant value		deg ⁻¹	MX
V97U0510C	C25	C20 constant value in linear term		deg ⁻¹	MX
V97U0511C	C26	C20 linear value		sec/ft-deg	MX
V97U0512C	C27	C20 constant value		deg ⁻¹	MX
V97U0514C	VC20	C20 velocity break point		ft/sec	MX
V97U0505C	DLAPLM	Limit value for DELALP		deg	SX
V97U0534C	DDMIN	Minimum drag error		ft/sec ²	SX
V99U7401C	VNOALP2	Velocity to start modulation if in roll reversal for TAL		ft/sec	MX
V99U6202C	ACN2	Time constant for roll reversal avoidance of auto PTI		sec	MX
V99U6204C	DYL2	Auto PTI DELAZ deadband Number 2		rad	MX
V99U6205C	DYL3	Auto PTI DELAZ deadband Number 3		rad	MX
V99U6206C	DYL4	Auto PTI DELAZ deadband Number 4		rad	MX
V97U9532C	DLZFAC	Low-energy logic: DELAZ factor for roll command computation		ND	MX
V97U9508C	DLZDB1	Low-energy logic: upper limit for roll command calculations		rad	MX
V97U9509C	DLZDB2	Low-energy logic: lower limit for roll command calculations		rad	MX
V97U9506C	ROLMN1	Low-energy logic: roll command lower limit		deg	MX
V97U9507C	ROLMN2	Low-energy logic: roll command upper limit		deg	MX
V97U9520C	DXRCHK	Low-energy logic: drag margin w.r.t. BEQGLM for DZFCTR incrementing		ft/sec ²	MX
V97U9521C	DLZLM1	Low-energy logic: DELAZ limit for DZFCTR incrementing		rad	MX
V97U9522C	DLZLM2	Low-energy logic: DELAZ limit for DZFCTR decrementing		rad	MX
V97U0112C	DEG_PER_RAD	Radians-to-degrees conversion factor	57.2957795131	deg/rad	X

4.5.2.14 Entry Guidance Roll Command (EGROLCMD).

The purpose of this function is to generate a roll attitude command for the flight control system (FCS) as well as compute the angle-of-attack command for the FCS upon initiation of alpha modulation. This function also computes an “unlimited” roll attitude command for telemetry monitoring availability as well as performs a roll attitude reference calculation for on-board, display monitoring utilization.

A. Detailed Requirements. EGLDVCMD provides vertical L/D commands based on ranging requirements while EGPEP provides the pre-entry, open loop, vertical L/D commands. Those vertical L/D commands are converted into roll commands in EGROLCMD by defining an intermediate parameter, ARG_i:

$$ARG_1 = LODV/XLOD$$

$$ARG_2 = LODX/XLOD$$

$$ARG_3 = ALDREF/XLOD$$

The roll commands are then generated by means of a “Do Loop.” First the ARG_i parameters are limited. The negative limit is chosen to preclude sudden polarity changes in ROLLC when it is close to 180 degrees. This could happen because of potential inaccuracies in the trigonometric functions outputs. Next, bank commands are calculated using RK2ROL and the \cos^{-1} of ARG_i. Finally, these bank commands are converted to body axis roll commands.

DO FOR I = 1 to 3

$$ARG_i = MIDVAL(ARG_i, -0.9999, 1.0)$$

$$ROLLC_i = RK2ROL \ ARCCOS(ARG_i)$$

$$ROLLC_i = ARCTAN2(SIN(ROLLC_i), \cos(ROLLC_i) \cos(ALPHA/DEG_PER_RAD))$$

DEG_PER_RAD

If angle-of-attack modulation has been enabled (ICT = 1) or the low-energy logic is engaged (ICNTAL = ON), a roll command bias is computed as a function of the difference between the actual versus scheduled angle of attack.

If ICT = 1 or ICNTAL = ON, then

$$DELALF = ALPHA - ACMD1$$

If the low-energy item entry (ILEFLG) is set and alpha has not yet converged to the alpha profile, the roll command bias is set to zero; otherwise the roll command bias is computed.

If ILEFLG = ON and IALCNV < 1,

then RDEALF = 0.0;

else RDEALF = MIDVAL(CRDEAF DELALF, RDMAX, -RDMAX)

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The FCS roll command is then updated to reflect the roll command bias as well as LMN derived, minimum roll angle, command constraints:

$$ALMNXD = ARCCOS(LMN/XLOD) \text{ DEG_PER_RAD}$$

$$ROLLC(1) = MIDVAL(ABS(ROLLC(2)) + RDEALF, ALMNXD, 180.-ALMNXD) \text{ RK2ROL}$$

An upper and lower α limit is computed:

$$ACLAM = ACMD1 + \text{MIN}(\text{SCALAR}(\text{DLALLM}, \text{ACLAM1} + \text{ACLAM2 VE}))$$

$$ACLIM = ACMD1 - \text{MIN}(\text{SCALAR}(\text{ACLIM1}, \text{ACLIM2} + \text{ACLIM3 VE}))$$

ALPCMD is then generated by:

$$ALPCMD = MIDVAL(ACLAM, \text{ALPHA} + \text{DELALP}, ACLIM)$$

The roll command to the FCS, ROLLC(1), is limited to an absolute value less than or equal to RLM if the velocity is less than VEROLC to ensure that large altitude rates do not incur dynamic pressure constraint exceedances during transition.

If $VE > \text{VRLMC}$, then

$$\text{RLM} = \text{MIN}(\text{SCALAR}(\text{RLMC1}, \text{RLMC2} + \text{RLMC3 VE}));$$

else

$$\text{RLM} = \text{MAX}(\text{SCALAR}(\text{RLMC6}, \text{RLMC4} + \text{RLMC5 VE}))$$

If $\text{ABS}(\text{ROLLC}_1) > \text{RLM}$ and $VE < \text{VEROLC}$, then

$$\text{ROLLC}_1 = \text{RLM} \text{ RK2ROL}$$

Status determination for the low-energy logic pullout indicator, IRDOT, will now be performed irrespective of whether or not the low-energy logic has been invoked. This processing is required to ensure proper moding of low-energy logic dependencies for possible, "late" engagement scenarios.

If pullout has not been determined to have occurred ($\text{IRDOT} < 2$), pullout completion tests will be performed. Pullout completion is defined as having occurred if the altitude rate becomes greater than a pullout test criterion (e.g., low speed contingency abort cases) or if the relative velocity is less than the alpha modulation velocity constraint (e.g., high speed, low-energy logic applications).

If $\text{IRDOT} < 2$, then Equation Set A is executed.

A.1 If $\text{RDOT} < 0.0$, then

$$\text{IRDOT} = 1$$

A.2 If $(\text{RDOT} > \text{RDOTPO}$ and $\text{IRDOT} > 0)$ or $VE < \text{VNOALP}$, then

$$\text{IRDOT} = 2$$

If the low-energy item entry is set (ILEFLG = ON), the following, described, low-energy logic dependencies will be exercised. Tests are first performed to check for engagement / disengagement of the low-energy logic. The contingency abort angle-of-attack profile and roll commands for phugoid flight will then be applied if the low-energy logic is engaged. If the low-energy logic becomes disengaged, angle-of-attack and roll commands will be generated for convergence to the nominal entry guidance reference profiles. The process is as follows:

- 1.1 The low-energy logic disengagement test is not performed if the logic is already disengaged or if pullout has not been completed. The disengagement test consists of comparing a linear representation of a biased equilibrium glide boundary to the drag reference profile. Low-energy logic disengagement will occur if the drag reference profile is above the biased equilibrium glide boundary.

If ICNTAL = ON and IRDOT > 1, then Equation Set B is executed.

- B.1 If $VE \geq VELMN$,
 - then $BEQGLM = EQGLM1(1) + EQGLM2(1) VE$
 - else $BEQGLM = EQGLM1(2) + EQGLM2(2) VE$
- B.2 If $DREFP > BEQGLM$, then ICNTAL = OFF

- 1.2 If the low-energy logic is engaged (ICNTAL = ON), then the low-energy angle-of-attack and roll commands are computed using Equation Set C as follows:

C.1 $ROLLC_1 = ROLLMN$

C.2 If $IRDOT < 2$, then execute Equations C.2.1 to C.2.5 to determine the alpha command for the initial pullout. Equation C.2.1 (ALP_WLE) computes a pullout alpha command based solely on velocity and drag acceleration to protect for wing leading edge thermal limitations. The alpha command to be output to the Flight Control System then becomes a function of the initial inertial velocity at Entry Guidance initialization using ALP_WLE and predefined pullout alpha command values.

$$C.2.1 \quad ALP_WLE = (VE \text{ DRAG}^{1/4}) / (ALP_WLE_C3 VE^3 + ALP_WLE_C2 VE^2 + ALP_WLE_C1 VE + ALP_WLE_C0)$$

$$C.2.2 \quad ALPCMD = MIDVAL(ALPHPO(1), ALP_WLE, ALPHPO_HI)$$

$$C.2.3 \quad \text{If } VI_INIT < VI_ALP_LO \text{ then } ALPCMD = ALPHPO(1)$$

$$C.2.4 \quad \text{If } VI_INIT > VI_ALP_HI \text{ then } ALPCMD = ALPHPO_HI$$

$$C.2.5 \quad ALPCA1 = ALPHA$$

Otherwise, execute Equation Set C.2.6 to determine the alpha command for the phugoids subsequent to the initial pullout.

$$C.2.6 \quad \text{If } VE < VALPMX, \text{ then } ALPCMD = ALPHTM + (ALPHMX - ALPHTM) (VE - V_TAEM) / (VALPMX - V_TAEM)$$

Otherwise, execute Equations C.2.6.1 through C.2.6.6. Equation C.2.6.1 (ALP_WLE) defines alpha command levels that protect for wing leading edge

thermal limitations. Equation C.2.6.4.1 (ALP_VT_DRG) defines alpha command levels to protect for vertical tail thermal limitations. ALP_VT_DRG is limited by ALPH_VT_MX and an upper boundary by equation C.2.6.2 (ALP_VT_LM).

$$\text{C.2.6.1} \quad \text{ALP_WLE} = (\text{VE DRAG}^{1/4}) / (\text{ALP_WLE_C3 VE}^3 + \text{ALP_WLE_C2 VE}^2 + \text{ALP_WLE_C1 VE} + \text{ALP_WLE_C0})$$

$$\text{C.2.6.2} \quad \text{ALP_VT_LM} = \text{ALP_VLM_C3 VE}^3 + \text{ALP_VLM_C2 VE}^2 + \text{ALP_VLM_C1 VE} + \text{ALP_VLM_C0}$$

$$\text{C.2.6.3} \quad \text{ALP_VT_LM} = \text{MIDVAL}(\text{ALPH_VT_MX}, \text{ALP_VT_LM}, \text{ALPHCA})$$

C.2.6.4 If $(\text{ALP_WLE} \leq \text{ALP_VT_LM})$ then execute equations C.2.6.4.1 and C.2.6.4.2

$$\text{C.2.6.4.1} \quad \text{ALP_VT_DRG} = \text{ALP_VTD_C3 DRAG}^3 + \text{ALP_VTD_C2 DRAG}^2 + \text{ALP_VTD_C1 DRAG} + \text{ALP_VTD_C0}$$

$$\text{C.2.6.4.2} \quad \text{ALPCA2} = \text{MIDVAL}(\text{ALPH_VT_MX}, \text{ALP_VT_DRG}, \text{ALP_VT_LM})$$

Otherwise $(\text{ALP_WLE} > \text{ALP_VT_LM})$, $\text{ALPCA2} = \text{ALP_WLE}$

$$\text{C.2.6.5} \quad \text{ALPCA1} = \text{ALPTMC ALPCA1} + \text{ALPCA2} (1.0 - \text{ALPTMC})$$

$$\text{C.2.6.6} \quad \text{ALPCMD} = \text{MIDVAL}(\text{ACLIM}, \text{ALPCA1}, \text{ALPHMX})$$

1.3 If the low-energy logic is disengaged ($\text{ICNTAL} = \text{OFF}$), the following logic is exercised:

If alpha has not converged to the nominal guidance profile, a check for convergence is made. If the magnitude of the difference between the commanded and actual angle-of-attacks is within a convergence test criterion, the alpha profile convergence flag is set; otherwise an alpha command is computed:

If $\text{IALCNV} < 1$, then Equation D.0 is executed.

D.0 If $\text{ABS}(\text{ALPCMD} - \text{ALPHA}) < \text{CNVTST}$, then $\text{IALCNV} = 1$

else

$$\text{ALPCMD} = \text{ALPHA} + \text{ALPRAT DTEGD SIGN}(\text{ALPCMD} - \text{ALPHA})$$

If drag has not converged to the drag reference profile, the drag profile convergence counter is computed, the convergence flag is set, and the roll command may be limited:

If $ICNVRG < 1$, then Equation Set E is executed.

E.1 If $ABS(DD) \leq DRCVRG$, then $NCNVRG = NCNVRG + 1$
else $NCNVRG = 0$

E.2 IF $NCNVRG > NDRGCN$, then $ICNVRG = 1$

E.3 If $ABS(DD) > DRLIM$ and $ICNVRG < 1$, then
 $ROLLC_1 = SIGN(ROLLC_1) \text{ MIN}(ABS(ROLLC_1), ROLLIM)$

1.4 If the low-energy logic is disengaged ($ICNTAL = OFF$) and convergence to the nominal entry guidance angle-of-attack and drag reference profiles has been attained, the low-energy item entry is set to inhibited:

If $ICNTAL = OFF$ and $IALCNV > 0$ and $ICNVRG > 0$, then $ILEFLG = OFF$

B. Interface Requirements. Table 4.5.2.14-1 presents the input and output parameters for EGROLCMD. The I-loads/constants are listed in Table 4.5.2.14-2.

C. Processing Requirements. EGROLCMD is processed at the normal entry guidance rate for the entire entry major mode.

D. Initialization Requirements. None.

Table 4.5.2.14-1. EGROLCMD Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
ACMD1	Nominal angle of attack command reference (i.e., scheduled angle of attack)	EGALPCMD	deg	F
LODV	Desired vertical L/D ratio	EGPEP, EGLODVCMD	ND	F
LODX	Desired, unlimited vertical L/D ratio	EGPEP, EGLODVCMD	ND	F
LMN	Vertical L/D cmd for minimum roll angles	EGLODVCMD	ND	F
XLOD	Limited lift/drag ratio	EGCOMN		
RK2ROL	Roll direction	EGLODVCMD, EGINIT	ND	F
ALDREF	Lift/drag reference	EGLODVCMD	ND	F
DELALP	$\Delta\alpha$ command	EGLODVCMD	deg	F
VE	Ground relative velocity magnitude	NAV	ft/sec	F
ICT	α modulation flag	EGLODVCMD, EGINIT	ND	I
ALPHA	Angle of attack	ADTA SOP	deg	F
ICNTAL	Low-energy logic engagement discrete	EGEXEC	ND	D
ILEFLG	Low-energy item entry	ENT TRAJ 1-5	ND	D

Table 4.5.2.14-1. EGROLCMD Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
IRDOT	Low-energy logic: pullout completion flag	EGINIT	ND	I
ROLLMN	Low-energy logic: roll command	EGLODVCMD	deg	F
ICNVRG	Low-energy logic: drag profile convergence flag	EGEXEC	ND	I
DD	Drag error	EGGNSLCT	ft/sec ²	F
NCNVRG	Low-energy logic: drag profile convergence counter	EGEXEC	ND	I
DREFP	Drag reference used in controller	EGINIT, EGREF, EGREF4, EGTRAN	ft/sec ²	F
VNOALP	α modulation velocity constraint	EGINIT, EGALPCMD, EGLODVCMD	ft/sec	F
RDOT	Current altitude rate with respect to oblate earth	NAV	ft/sec	F
IALCNV	Low-energy logic: alpha profile convergence flag	EGEXEC	ND	I
ALPCA1	Low-energy logic: filtered alpha command	EGEXEC	deg	F
VI_INIT	Low-energy logic: initial value of inertial velocity	EGINIT	ft/sec	F
DRAG	Vehicle drag acceleration	NAV	ft/sec ²	F
ALPHPO_HI	Low-energy logic: maximum initial pullout alpha command limit	EGINIT	deg	F
OUTPUTS				
ROLLC(1)	Commanded roll angle about the X body axis	AEROJET DAP, TLM, ENT TRAJ 1-5, E/L ADI PROC, EGCOMN, MEDS FC GNC XFER	deg	F
ROLLC(2)	Unlimited roll command	TLM	deg	F
ROLLC(3)	Roll reference angle	ENT TRAJ 1-5, ENT DIP, TLM	deg	F
ALPCMD	Angle-of-attack command	AEROJET DAP, TLM	deg	F
ICNTAL	Low-energy logic engagement discrete	ENT TRAJ 1-5, EGCOMN, EGRP, TLM, EGTRAN, EGEXEC, EGLODVCMD	ND	D
ILEFLG	Low-energy item entry	ENT TRAJ 1-5, TLM	ND	D
BEQGLM	Low-energy logic: biased equilibrium glide boundary	EGLODVCMD	ft/sec ²	F

Table 4.5.2.14-2. EGROLCMD I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0112C	DEG_PER_RAD	Radians-to-degrees conversion factor	57.2957795131	deg/rad	X
V97U0470C	RLMC1	Maximum value of RLM		deg	SX
V97U0471C	RLMC2	Coefficient in first RLM segment		deg	SX
V97U0472C	RLMC3	Coefficient in first RLM segment		deg-sec/ft	SX
V97U0473C	RLMC4	Coefficient in second RLM segment		deg	SX
V97U0474C	RLMC5	Coefficient in second RLM segment		deg-sec/ft	SX
V97U0475C	RLMC6	Minimum value of RLM		deg	SX
V97U0476C	VRLMC	Velocity to switch RLM segments		ft/sec	SX
V97U0434C	VEROLC	Maximum velocity for limiting the roll angle command		ft/sec	SX
V97U0501C	CRDEAF	Gain on roll bias for α modulation		ND	SX
V97U0497C	ACLIM1	Minimum α constant		deg	SX
V97U0498C	ACLIM2	Minimum α constant		deg	SX
V97U0499C	ACLIM3	Minimum α constant		deg-sec/ft	SX
V97U0504C	DLALLM	Maximum α constant		deg	SX
V97U0495C	ACLAM1	Maximum α constant		deg	SX
V97U0496C	ACLAM2	Maximum α constant		deg-sec/ft	SX
V97U0535C	RDMAX	Maximum roll bias		deg	SX
V97U9501C	ALPHCA	Low-energy logic: contingency abort alpha command limit – post-pullout		deg	MX
V97U9502C	ALPHMX	Low-energy logic: contingency abort alpha command – maximum L/D		deg	MX
V97U9527C	VALPMX	Low-energy logic: velocity to begin contingency abort alpha command ramp		ft/sec	MX
V97U9504C	ALPHTM	Low-energy logic: contingency abort alpha command – entry-TAEM interface		deg	MX
V97U0420C	V_TAEM	Reference velocity at entry-TAEM interface	2500.0	ft/sec	K
V97U9513C	DRCVRG	Low-energy logic: drag threshold for convergence test		ft/sec ²	MX
V97U9524C	NDRGCN	Low-energy logic: drag profile convergence counter target		ND	MX
V97U9514C	DRLIM	Low-energy logic: drag threshold for roll limiting during convergence to reference profile		ft/sec ²	MX
V97U9505C	ALPTMC	Low-energy logic: alpha ramp filter constant		ND	MX

Table 4.5.2.14-2. EGROLCMD I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0433C	VELMN	Maximum velocity for using ALMN3 limit		ft/sec	SX
V97U9516C	EQGLM1(1)	Low-energy logic: BEQGLM constant term		ft/sec ²	MX
V97U9517C	EQGLM1(2)	Low-energy logic; BEQGLM constant term		ft/sec ²	MX
V97U9518C	EQGLM2(1)	Low-energy logic: BEQGLM coefficient		sec ⁻¹	MX
V97U9519C	EQGLM2(2)	Low-energy logic: BEQGLM coefficient		sec ⁻¹	MX
V97U6100C	DTEGD	Entry guidance cycle interval	1.92	sec	X
V97U9531C	CNVTST	Low-energy logic: alpha profile convergence test criterion		deg	MX
V97U9515C	RDOTPO	Low-energy logic: pullout altitude rate		ft/sec	MX
V97U9525C	ROLLIM	Low-energy logic: roll command limit for convergence to drag profile		deg	MX
V97U9530C	ALPRAT	Low-energy logic: alpha convergence rate		deg/sec	MX
V97U2023C	ALP_VLM_C0	Low-energy logic: constant term in equation to limit alpha command based on vertical tail thermal		deg	MX
V97U2024C	ALP_VLM_C1	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec/ft	MX
V97U2025C	ALP_VLM_C2	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec**2/ft**2	MX
V97U2026C	ALP_VLM_C3	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec**3/ft**3	MX
V97U2028C	ALP_VTD_C0	Low-energy logic: constant term in equation to limit alpha command based on vertical tail thermal		deg	MX
V97U2029C	ALP_VTD_C1	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec**2/ft	MX
V97U2030C	ALP_VTD_C2	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec**4/ft**2	MX
V97U2031C	ALP_VTD_C3	Low-energy logic: coefficient in equation to limit alpha command based on vertical tail thermal		deg*sec**6/ft**3	MX

Table 4.5.2.14-2. EGROLCMD I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U2016C	ALP_WLE_C0	Low-energy logic: constant term in equation to limit alpha command based on wing leading edge thermal		ft**1.25/ deg*sec** 1.5	MX
V97U2017C	ALP_WLE_C1	Low-energy logic: coefficient in equation to limit alpha command based on wing leading edge thermal		ft**.25/ deg*sec**.5	MX
V97U2018C	ALP_WLE_C2	Low-energy logic: coefficient in equation to limit alpha command based on wing leading edge thermal		sec**.5/ deg*ft**.75	MX
V97U2019C	ALP_WLE_C3	Low-energy logic: coefficient in equation to limit alpha command based on wing leading edge thermal		sec**1.5/ deg*ft** 1.75	MX
V97U2027C	ALPH_VT_MX	Low-energy logic: minimum alpha command limit for vertical tail thermal		deg	MX
V97U9503C	ALPHPO(1)	Low-energy logic: minimum initial pullout alpha command		deg	MX
V97U2022C	VI_ALP_HI	Low-energy logic: inertial velocity to limit alpha command to upper limit		ft/sec	MX
V97U2021C	VI_ALP_LO	Low-energy logic: inertial velocity to limit alpha command to lower limit		ft/sec	MX

4.5.3 Entry Guidance Data Flow

Figures 4.5.3-1 and 4.5.3-2 summarize the internal and external entry guidance data flow. The use of both variables and mission dependent constants are shown in the figures.

Constants that may be uplinked during flight are denoted by MX (mission dependent constants). Candidate parameters for downlink telemetry include all uplink data and the following variables:

DOWNLINK PARAMETERS

ALDREF, ALPCMD, C4, C16, C17, DELAZ, DRAG, DRDD, DREFP, DREF(1), DREF(2), D23, EEF, HS, ISLECT, HDTRF(1), HDTRF(2), LODV, RDTRF, DREFP3, DREFP4, DREFP5, RFF1, REQ1, RCG, RK2ROL, ROLLC, RPT, TRANGE, T1, T2, VCG, XLFAC, XL0D, C2, DRF, D231, RDTRF, DLRDOT, ZK, ICT, RDEALF, ICNTAL, ILEFLG

These parameters are candidates only. The actual uplink and downlist requirements are baselined and controlled by the appropriate uplink/downlist requirements documents.

Parameters going to the display interface (DI) for the entry CRT displays are ACMD1, DLRDOT, DRDD, DREFP, ISLECT, RDTRF, T2, ROLLC(1), YL, ICNTAL, ILEFLG, and ROLLC(3).

Commands to the flight control system (FC) are: ALPCMD, ROLLC(1).

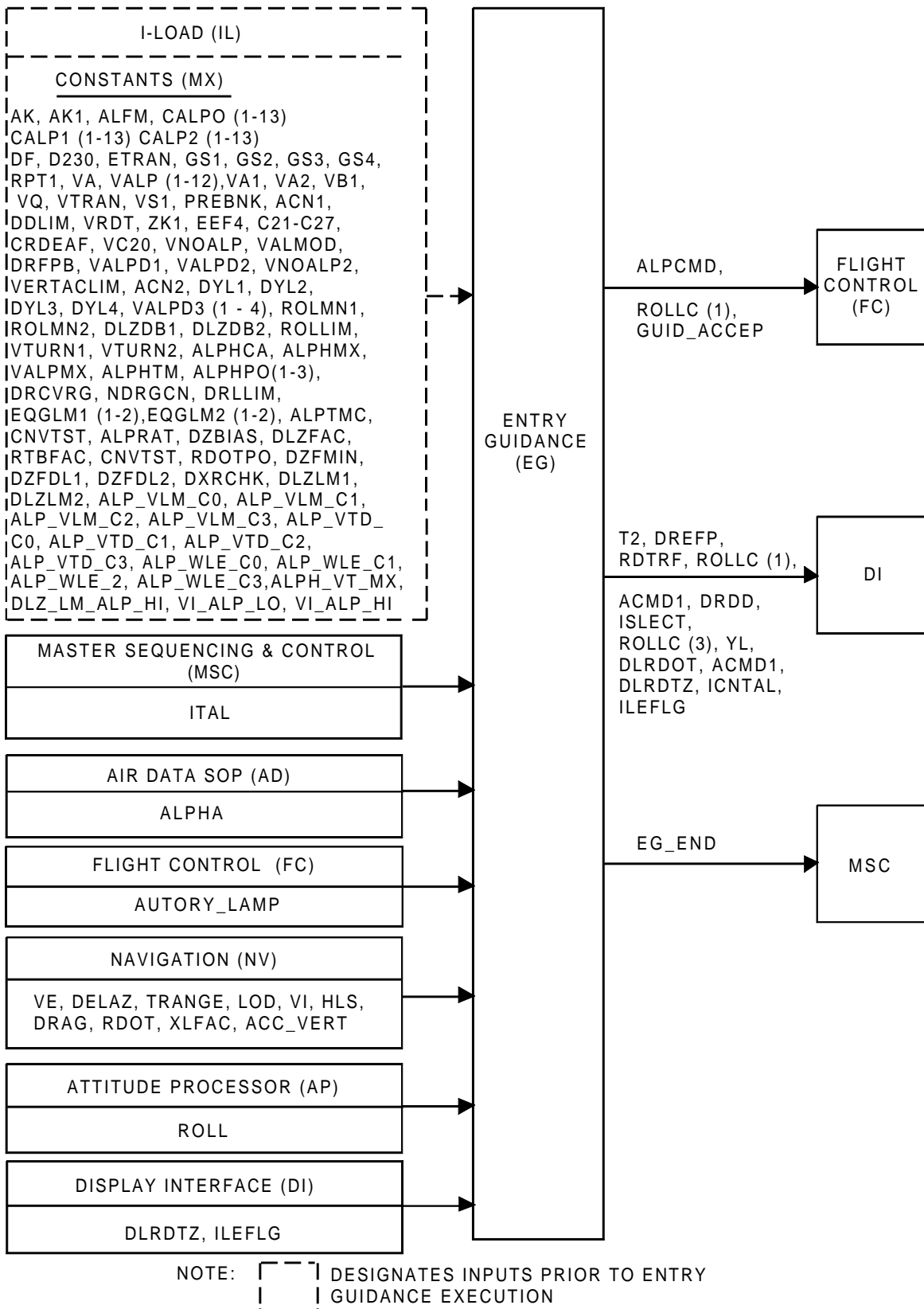


FIGURE 4.5.3-1. Entry Guidance External Data Flow Summary

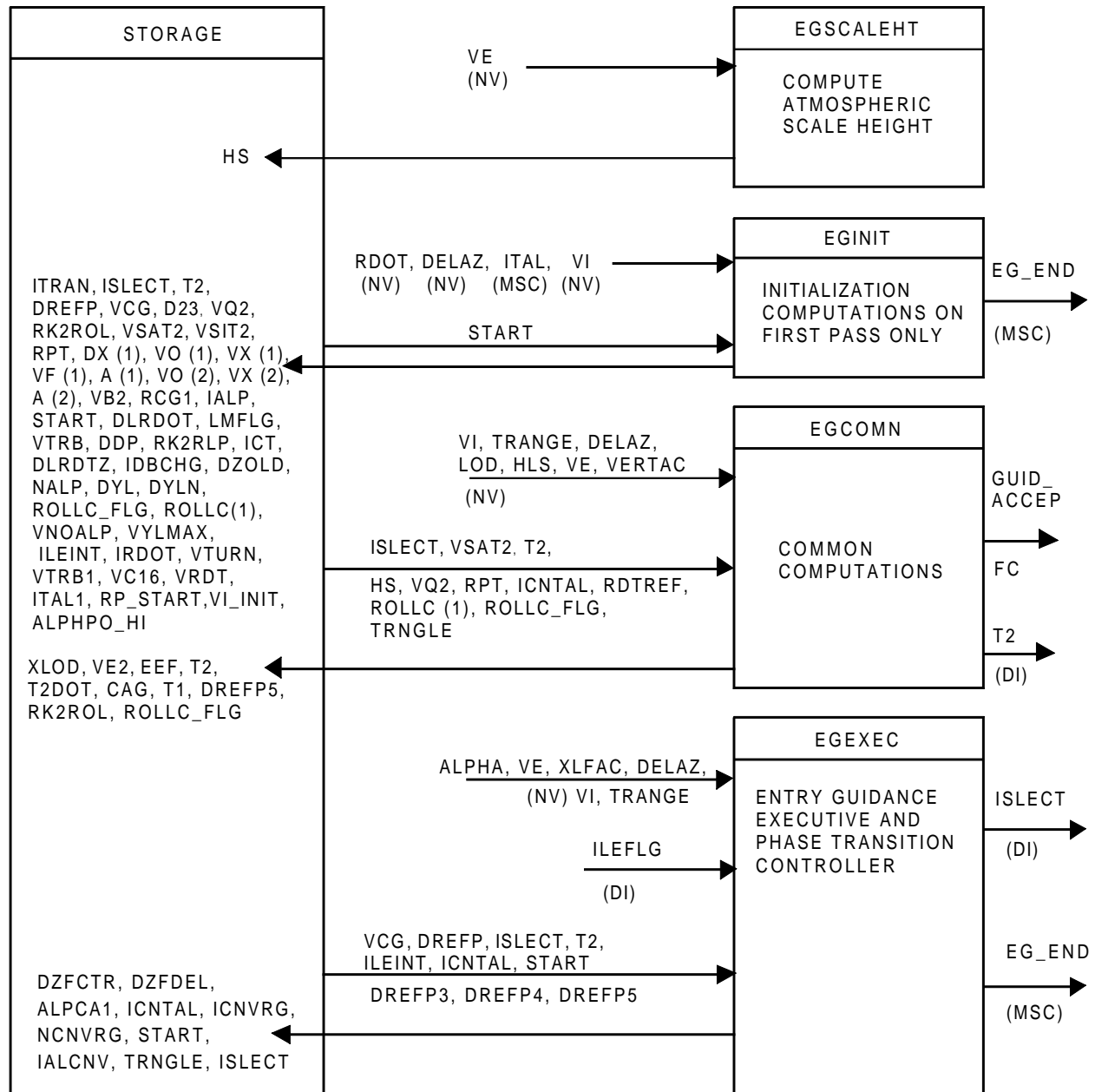


FIGURE 4.5.3-2.(1) Entry Guidance Internal Data Flow Summary (Sheet 1 of 4)

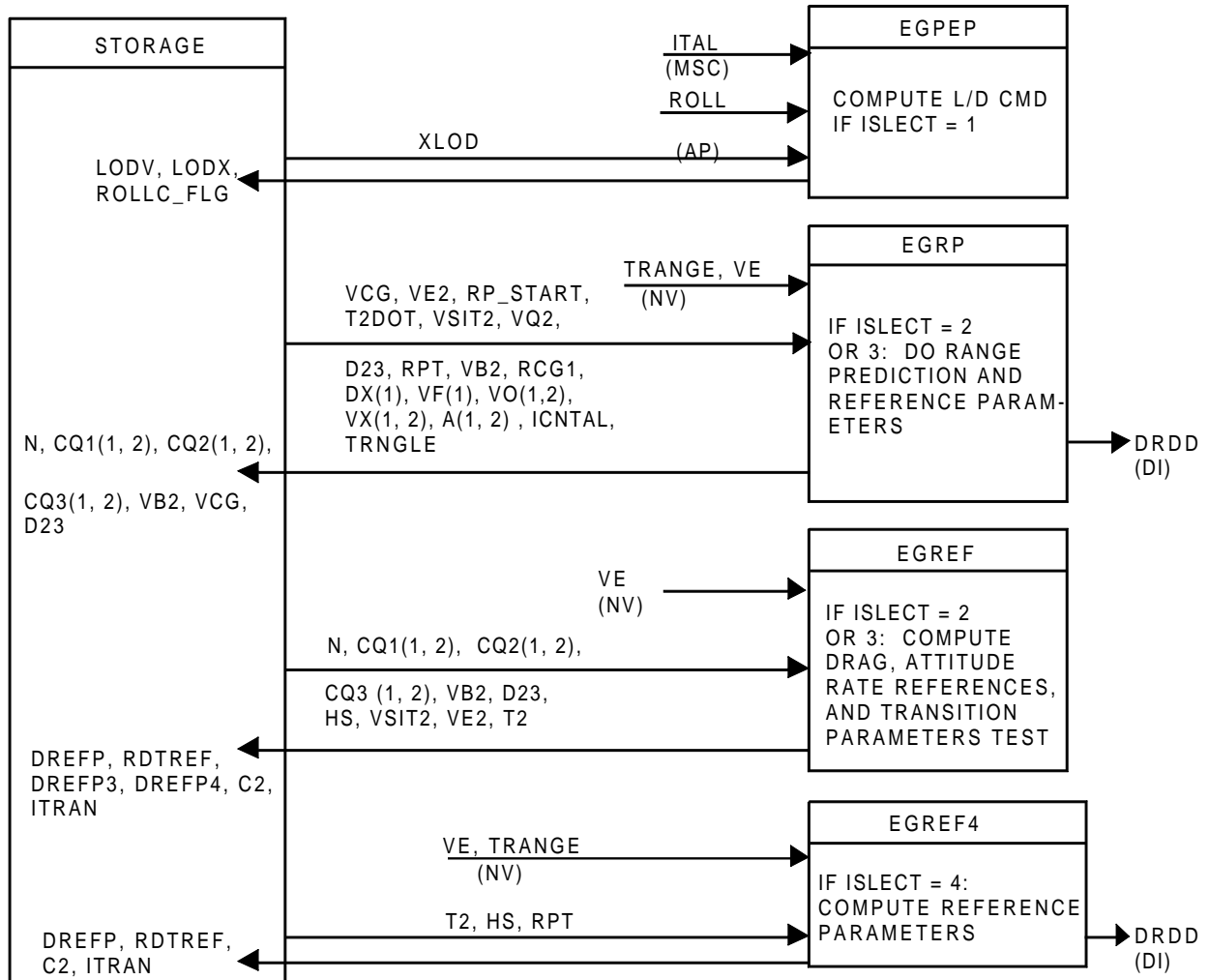


FIGURE 4.5.3-2.(2) Entry Guidance Internal Data Flow Summary (Sheet 2 of 4)

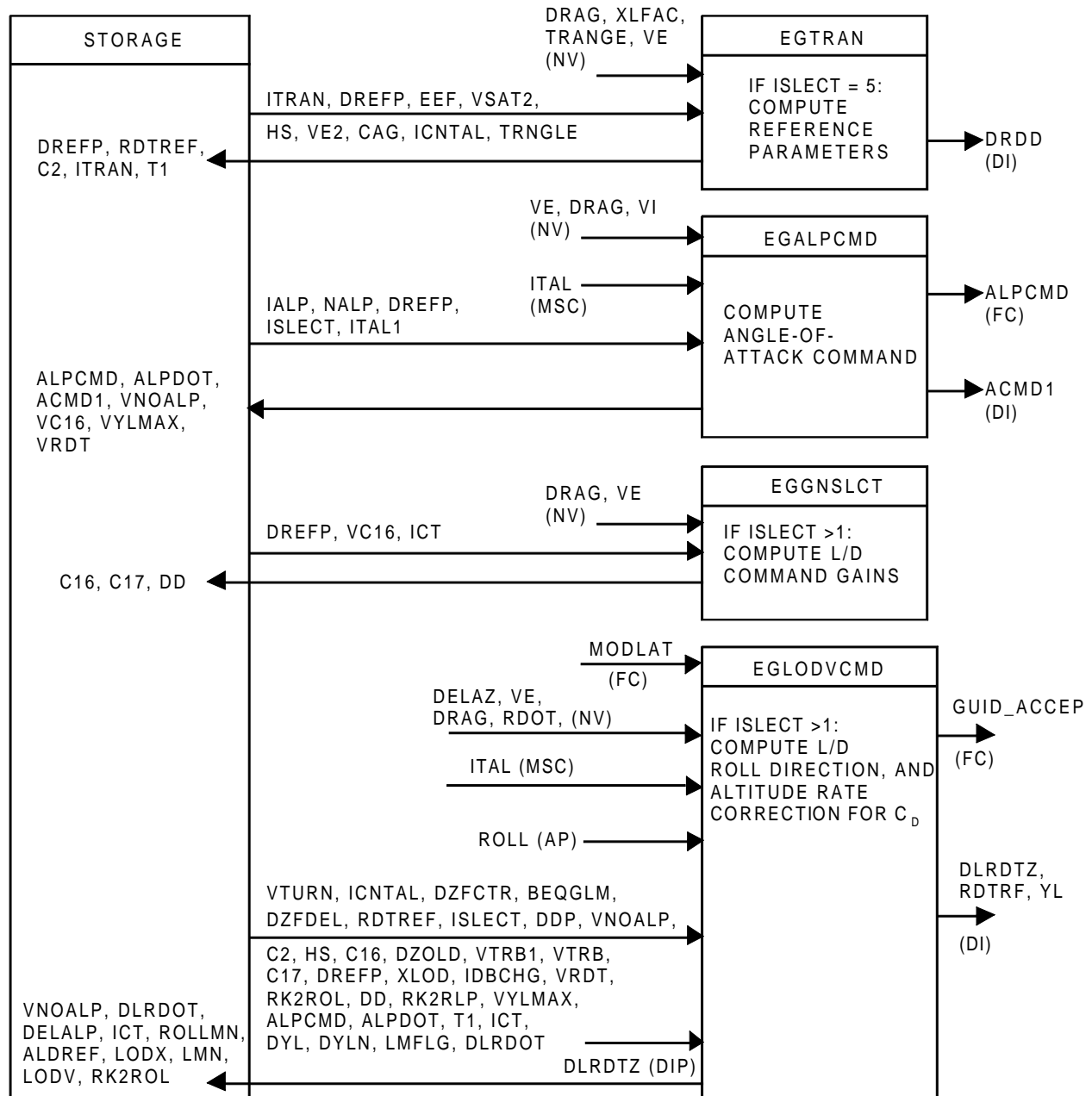


FIGURE 4.5.3-2.(3) Entry Guidance Internal Data Flow Summary (Sheet 3 of 4)

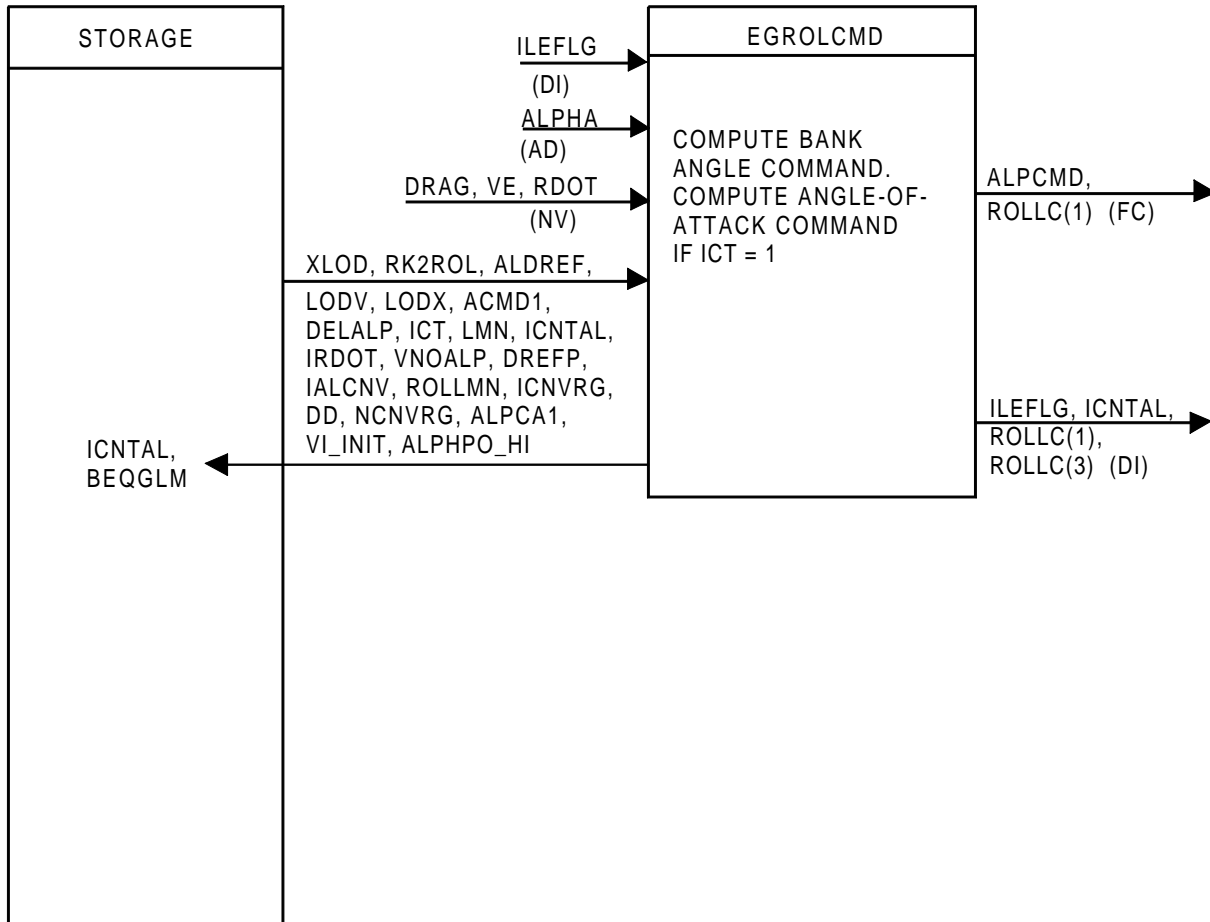


FIGURE 4.5.3-2.(4) Entry Guidance Internal Data Flow Summary (Sheet 4 of 4)

4.5.4 Parameter Tables For Entry Guidance (G4.8)

The IDD inputs and outputs are listed in Tables 4.5.4-1 and 4.5.4-2 respectively. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.5.4-3. K-loads are listed in Table 4.5.4-4. Constants are listed in Table 4.5.4-5.

TABLE 4.5.4-1. INPUT FUNCTIONAL PARAMETERS FOR ENTRY GUIDANCE (G4.8)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ACC_DRAG	V95A0160CB	DRAG DECEL	ENT UPP	FT/S2			93017G	*
ACC_VERT	V95A0170CB	VERTICAL ACCEL IN TOPODETTIC COORD	ENT UPP	FT/S2				
ALPHA	V95H3021C	GN&C ANGLE OF ATTACK	ADTA SOP	DEG	SPL		93017G	*
ALT_WHEELS	V95H0165CB	ALT TO REAR WHEELS/NAV BASE(ENTRY)	ENT UPP	FT	DPL		93017G	*
AUTORY_IND/AUTORY_LAMP	V90X1642XA	ROLL/YAW AUTO FLAG	AEROJET DAP				92522D	
DELAZ	V95H0172C	HEADING ERR WRT HAC TANGENT POINT	ENT UPP	RAD	SPL		93017G	*
DLRDTZ	V93X5201XA	ZERO H DOT BIAS CMD	ENTRY TRAJ1					
DLRDTZ	V93X5201XB	ZERO H DOT BIAS CMD	ENTRY TRAJ2					
DLRDTZ	V93X5201XC	ZERO H DOT BIAS CMD	ENTRY TRAJ3					
DLRDTZ	V93X5201XD	ZERO H DOT BIAS CMD	ENTRY TRAJ4					
DLRDTZ	V93X5201XE	ZERO H DOT BIAS CMD	ENTRY TRAJ5					
H_DOT_ELLIPSOID/H_DOT	V95L0265CD	EST ALTITUDE RATE	ENT UPP	FT/S	SPL		93017G	*
ILEFLG	V93X0080XA	LOW-ENERGY ITEM ENTRY	ENTRY TRAJ1		BD		93017G	*
ILEFLG	V93X0080XB	LOW-ENERGY ITEM ENTRY	ENTRY TRAJ2		BD		93017G	*
ILEFLG	V93X0080XC	LOW-ENERGY ITEM ENTRY	ENTRY TRAJ3		BD		93017G	*
ILEFLG	V93X0080XD	LOW-ENERGY ITEM ENTRY	ENTRY TRAJ4				93017G	*
ILEFLG	V93X0080XE	LOW-ENERGY ITEM ENTRY	ENTRY TRAJ5		BD		93017G	*
LOAD_TOTAL	V95U0163CA	TOTAL LOAD FACTOR	ENT UPP	FT/S2			93017G	*
LOD	V95U0180C	LIFT/DRAG	ENT UPP		SPL		93017G	*
PHI/PHI_TOPO	V90H2202C	BODY ROLL ATTITUDE EULER ANGLE	A/E ATT PROC	DEG	SPL		93017G	*
REL_VEL_MAG/V	V95L0151CC	GND REL VEL MAGNITUDE IN M50 SYS	ENT UPP	FT/S	SPL		93017G	*
RNG_TO_RW_THRESH	V95H0176CA	RANGE TO RUNWAY THRESHOLD VIA WP1	ENT UPP	NM			93017G	*
TAL_ABORT_DECLARED	V90X8658X	TAL ABORT DECLARED	MSC				93090E	
V_MAG	V95L0150C	VEHICLE INERTIAL SPEED	ENT UPP	FT/S			93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.5.4-2. OUTPUT FUNCTIONAL PARAMETERS FROM ENTRY GUIDANCE (G4.8)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ACMD1	V90H1192C	SCHEDULED ANGLE OF ATTACK	ENT DIP	DEG			92354	
ALDREF	V90U1148C	LIFT/DRAG REFERENCE	DL FMT 23/A		SPL		93017G	*
ALPCMD	V90H0803CA	COMMANDED ANGLE OF ATTACK	AEROJET DAP DL FMT 23/A	DEG			93017G	*
C16	V90R1150C	CONTROLLER GAIN-C16	TLM	S2/FT				
C17	V90R1151C	CONTROLLER GAIN-C17	TLM	S/FT				
C2	V90U1191C	COMP OF L/D REF USED IN CONTROLLER	TLM	1/S				
D23	V90A1157C	REF DRAG EQLIB GLIDE & ANCHOR DRAG	TLM	FT/S2				
D231	V90A1197C	1ST UPDATED VALUE OF DRAG REF	TLM	FT/S2				
DLRDOT	V90R1133C	ALTITUDE RATE FEEDBACK CORRECTION	DL FMT 23/1 ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5	FT/S	SPL		93017G	*
DRDD	V90R1137C	DERIVATIVE OF RANGE WRT DRAG	DL FMT 23/A ENT DIP	NM	SPL		93017G	*
DREF(1)	V90A1155C	DRAG REF DURING TEMP CONTROL-1	TLM					
DREF(2)	V90A1156C	DRAG REF DURING TEMP CONTROL-2	TLM					
DREFP	V90A1135C	REF DRAG	DL FMT 23/1 ENT DIP	FT/S2	SPL		93017G	*
DREFP3	V90U1170C	TEST VALUE DREFP TRANS TO PHASE 3	TLM	FT/S2				
DREFP4	V90U1171C	TEST VALUE DREFP TRANS TO PHASE 4	TLM	FT/S2				
DREFP5	V90U1172C	TEST VALUE DREFP TRANS TO PHASE 5	TLM	FT/S2				
DRF	V90U1195C	TEST VALUE DURING TEMP CNTL PHASE	TLM					
EEF	V90U1160C	CURRENT ENERGY/MASS	DL FMT 23/A	FT2/S2	SPL		93017G	*
EG_END	V90X1140X	ENTRY GUIDANCE TERMINATION FLAG	DL FMT 23/A MSC		BD		93017G	*
GUID_ACCEPT	V90X1200XA	AUTO PTI ACCEPTABLE DISCRETE	PTI				89740B	
HDTRF(1)	V90R1164C	ALT RATE REF DURING TEMP CNTL-1	TLM	S				
HDTRF(2)	V90R1165C	ALT RATE REF DURING TEMP CNTL-2	TLM	S				
HS	V90H1162C	ATMOSPHERIC DENSITY SCALE HEIGHT	TLM	FT				
ICNTAL	V90X1198X	LOW-ENERGY LOGIC ENGAGE DISCRETE	DL FMT 23/1 ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5		BD		93017G	*
ILEFLG	V93X0080X	LOW-ENERGY ITEM ENTRY	DL FMT 23/1 ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5		BD		93017G	*

TABLE 4.5.4-2. OUTPUT FUNCTIONAL PARAMETERS FROM ENTRY GUIDANCE (G4.8)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ISLECT	V90J1138C	ENTRY GUID SUBPHASE INDICATOR	DL FMT 23/1 ENT DIP MEDS FC GNC XFER		HXS		93017G	*
LODV	V90U1168C	DESIRED VERTICAL L/D RATIO	TLM					
RCG	V90H1178C	CONSTANT DRAG PHASE RANGE	TLM	NM				
RDRF	V90R1199C	NOM VALUE OF ALT RATE REF	DL FMT 23/1 ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5	FT/S	SPL		93017G	*
REQ1	V90U1176C	EQUILIBRIUM GLIDE RANGE-DRAG PRODUCT	TLM	NM-FT/S2			90185A	
RFF1	V90U1175C	TEMP CNTL RANGE-DRAG PRODUCT	TLM	NM-FT/S2			90185A	
RK2ROL	V90H1179C	ROLL COMMAND DIRECTION	TLM					
ROLLC(1)	V90H1044CC	COMMANDED ROLL ANGLE	AEROJET DAP DL FMT 23/A E/L ADI PROC ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5 MEDS FC GNC XFER	DEG			93017G	*
ROLLC(2)	V90H1031CD	UNLIMITED ROLL COMMAND	TLM	DEG			90881A	
ROLLC(3)	V90H1142C	REF ROLL ANGLE	DL FMT 23/1 ENT DIP ENTRY TRAJ1 ENTRY TRAJ2 ENTRY TRAJ3 ENTRY TRAJ4 ENTRY TRAJ5	DEG	SPL		93017G	*
RPT	V90H1180C	DSRD RNG END OF CONST DRAG PHASE	TLM	NM				
T1	V90A1185C	VERT LIFT ACCEL FOR EQUILIB GLIDE	TLM	FT/S2				
T2	V90A1134C	CONST DRAG LEVEL TO REACH TARGET	DL FMT 23/1 ENT DIP	FT/S2	SPL		93017G	*
VCG	V90L1188C	EQUILIB GLIDE/CONST DRAG BNDRY VEL	DL FMT 23/1	FT/S	SPL		93017G	*
XL0D	V90U1190C	LIFT OVER DRAG RATIO	DL FMT 23/1		SPL		93017G	*
YL	V90H1183C	MAXIMUM HEADING ERROR ABS VALUE	ENT DIP	RAD				
	V90M2947P	CGGB_CO3_FLAG_1	DL FMT 23/A				93017G	*
	V99M1854P	LANDING CONFIGURATION	DL FMT 23/1				93017G	*

TABLE 4.5.4-2. OUTPUT FUNCTIONAL PARAMETERS FROM ENTRY GUIDANCE (G4.8)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.5.4-3. ENTRY GUIDANCE (G4.8) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
ACLAM1	V97U0495C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
ACLAM2	V97U0496C	DEG*SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
ACLIM1	V97U0497C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
ACLIM2	V97U0498C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
ACLIM3	V97U0499C	DEG*SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
ACN1	V97U0006C	SEC	F	S	D	C	G4.8	00	ZFI	89484C	
ACN2	V99U6202C	SEC	F	S	M	P	G4.8	00	PTI	DC0599	
AK	V97U0007C	ND	F	S	M	C	G4.8	00	GDE	89484C	
AK1	V97U0008C	ND	F	S	M	C	G4.8	00	GDE	89484C	
ALFM	V97U0009C	FT/SEC**2	F	S	M	C	G4.8	00	GDE	89484C	
ALIM	V97U0010C	FT/SEC**2	F	S	D	C	G4.8	00	ZFI	89484C	
ALMN1	V97U0011C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
ALMN2	V97U0012C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
ALMN3	V97U0013C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
ALMN4	V97U0014C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
ALPHCA	V97U9501C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
ALPHMX	V97U9502C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
ALPHPO(1)	V97U9503C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALPHPO(2)	V97U2020C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALPHPO(3)	V97U2032C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALPHTM	V97U9504C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
ALPH_VT_MX	V97U2027C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALPRAT	V97U9530C	DEG/SEC	F	S	M	P	G4.8	00	GLE	90152D	
ALPTMC	V97U9505C	ND	F	S	M	P	G4.8	00	GLE	90152D	
ALP_VLM_C0	V97U2023C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VLM_C1	V97U2024C	DEG*SEC/FT	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VLM_C2	V97U2025C	DEG*SEC**2/FT**2	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VLM_C3	V97U2026C	DEG*SEC**3/FT**3	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VTD_C0	V97U2028C	DEG	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VTD_C1	V97U2029C	DEG*SEC**2/FT	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VTD_C2	V97U2030C	DEG*SEC**4/FT**2	F	S	M	P	G4.8	00	GLE	92671A	
ALP_VTD_C3	V97U2031C	DEG*SEC**6/FT**3	F	S	M	P	G4.8	00	GLE	92671A	
ALP_WLE_C0	V97U2016C	FT**1.25/DEG*SEC**1.5	F	S	M	P	G4.8	00	GLE	92671A	
ALP_WLE_C1	V97U2017C	FT** .25/DEG*SEC** .5	F	S	M	P	G4.8	00	GLE	92671A	
ALP_WLE_C2	V97U2018C	SEC** .5/DEG*FT** .75	F	S	M	P	G4.8	00	GLE	92671A	
ALP_WLE_C3	V97U2019C	SEC**1.5/DEG*FT**1.75	F	S	M	P	G4.8	00	GLE	92671A	
ASTART	V97U0042C	FT/SEC**2	F	S	D	C	G4.8	00	ZFI	89484C	
C17MP	V97U0502C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
C21	V97U0506C	DEG** -1	F	S	M	C	G4.8	00	ZFI	89484C	
C22	V97U0507C	DEG** -1	F	S	M	C	G4.8	00	ZFI	89484C	
C23	V97U0508C	SEC/FT*DEG	F	S	M	C	G4.8	00	ZFI	89484C	
C24	V97U0509C	DEG** -1	F	S	M	C	G4.8	00	ZFI	89484C	
C25	V97U0510C	DEG** -1	F	S	M	C	G4.8	00	ZFI	89484C	
C26	V97U0511C	SEC/FT*DEG	F	S	M	C	G4.8	00	ZFI	89484C	
C27	V97U0512C	DEG** -1	F	S	M	C	G4.8	00	ZFI	89484C	
CALP0(1)	V97U0043C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(10)	V97U0481C	DEG	F	S	M	C	G4.8	00	GDE	89484C	

TABLE 4.5.4-3. ENTRY GUIDANCE (G4.8) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
CALP0(11)	V99U7385C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(12)	V99U7386C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(13)	V99U7387C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(2)	V97U0044C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(3)	V97U0045C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(4)	V97U0046C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(5)	V97U0047C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(6)	V97U0048C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(7)	V97U0049C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(8)	V97U0479C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP0(9)	V97U0480C	DEG	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(1)	V97U0050C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(10)	V97U0484C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(11)	V99U7388C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(12)	V99U7389C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(13)	V99U7390C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(2)	V97U0051C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(3)	V97U0052C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(4)	V97U0053C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(5)	V97U0054C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(6)	V97U0055C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(7)	V97U0056C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(8)	V97U0482C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP1(9)	V97U0483C	DEG*SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(1)	V97U0057C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(10)	V97U0487C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(11)	V99U7391C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(12)	V99U7392C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(13)	V99U7393C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(2)	V97U0058C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(3)	V97U0059C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(4)	V97U0060C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(5)	V97U0061C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(6)	V97U0062C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(7)	V97U0063C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(8)	V97U0485C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CALP2(9)	V97U0486C	DEG*SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
CDDOT1	V97U0064C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT2	V97U0065C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT3	V97U0066C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT4	V97U0067C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT5	V97U0068C	DEG**-1	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT6	V97U0069C	DEG**-2	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT7	V97U0070C	SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT8	V97U0071C	DEG**-2	F	S	D	C	G4.8	00	ZFI	89484C	
CDDOT9	V97U0072C	DEG**-1	F	S	D	C	G4.8	00	ZFI	89484C	
CNVST	V97U9531C	DEG	F	S	M	P	G4.8	00	GLE	90152D	

TABLE 4.5.4-3. ENTRY GUIDANCE (G4.8) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
CRDEAF	V97U0501C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
CT16(1)	V97U0078C	SEC**2/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT16(2)	V97U0079C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
CT16(3)	V97U0080C	SEC**4/FT**2	F	S	D	C	G4.8	00	ZFI	89484C	
CT16MN	V97U0081C	SEC**2/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT16MX	V97U0082C	SEC**2/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT17(1)	V97U0083C	SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT17(2)	V97U0084C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
CT17M2	V97U0503C	SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT17MN	V97U0085C	SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CT17MX	V97U0086C	SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CY1	V97U0110C	RAD*SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
CYO	V97U0109C	RAD	F	S	D	C	G4.8	00	ZFI	89484C	
D230	V97U0141C	FT/SEC**2	F	S	M	C	G4.8	00	GDT	DC0599	
DDLIM	V97U0111C	FT/SEC**2	F	S	D	C	G4.8	00	ZFI	89484C	
DDMIN	V97U0534C	FT/SEC**2	F	S	D	C	G4.8	00	ZFI	89484C	
DELV	V97U0118C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
DF	V97U0121C	FT/SEC**2	F	S	M	C	G4.8	00	GDE	89484C	
DLALLM	V97U0504C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
DLAPLM	V97U0505C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
DLRDTM	V97U0477C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
DLZDB1	V97U9508C	RAD	F	S	M	P	G4.8	00	GLE	90152D	
DLZDB2	V97U9509C	RAD	F	S	M	P	G4.8	00	GLE	90152D	
DLZFAC	V97U9532C	ND	F	S	M	P	G4.8	00	GLE	90152D	
DLZLM1	V97U9521C	RAD	F	S	M	P	G4.8	00	GLE	90152D	
DLZLM2	V97U9522C	RAD	F	S	M	P	G4.8	00	GLE	90152D	
DLZ_LM_ALP_HI	V97U2033C	RAD	F	S	M	P	G4.8	00	GLE	92671A	
DRCVRG	V97U9513C	FT/SEC**2	F	S	M	P	G4.8	00	GLE	90152D	
DRDDL	V97U0128C	NMI*SEC**2/FT	F	S	D	C	G4.8	00	ZFI	89484C	
DRFPB	V99U7397C	FT/SEC**2	F	S	M	C	G4.8	00	GDE	89484C	
DRLLIM	V97U9514C	FT/SEC**2	F	S	M	P	G4.8	00	GLE	90152D	
DT2MIN	V97U0140C	FT/SEC**3	F	S	D	C	G4.8	00	ZFI	89484C	
DXRCHK	V97U9520C	FT/SEC**2	F	S	M	P	G4.8	00	GLE	90152D	
DYL1	V99U6203C	RAD	F	S	M	P	G4.8	00	PTI	DC0599	
DYL2	V99U6204C	RAD	F	S	M	P	G4.8	00	PTI	DC0599	
DYL3	V99U6205C	RAD	F	S	M	P	G4.8	00	PTI	DC0599	
DYL4	V99U6206C	RAD	F	S	M	P	G4.8	00	PTI	DC0599	
DZBIAS	V97U9533C	RAD	F	S	M	P	G4.8	00	GLE	90152D	
DZFDL1	V97U9511C	ND	F	S	M	P	G4.8	00	GLE	90152D	
DZFDL2	V97U9512C	SEC/FT	F	S	M	P	G4.8	00	GLE	90152D	
DZFMIN	V97U9510C	ND	F	S	M	P	G4.8	00	GLE	90152D	
EEF4	V97U0160C	FT**2/SEC**2	F	S	M	C	G4.8	00	GDE	89484C	
EQGLM1(1)	V97U9516C	FT/SEC**2	F	S	M	P	G4.8	00	GLE	90152D	
EQGLM1(2)	V97U9517C	FT/SEC**2	F	S	M	P	G4.8	00	GLE	90152D	
EQGLM2(1)	V97U9518C	SEC** -1	F	S	M	P	G4.8	00	GLE	90152D	
EQGLM2(2)	V97U9519C	SEC** -1	F	S	M	P	G4.8	00	GLE	90152D	
ETRAN	V97U0227C	FT**2/SEC**2	F	S	M	C	G4.8	00	GDE	89484C	

TABLE 4.5.4-3. ENTRY GUIDANCE (G4.8) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
GS1	V97U0259C	SEC**-1	F	S	M	C	G4.8	00	ZFI	89484C	
GS2	V97U0260C	SEC**-1	F	S	M	C	G4.8	00	ZFI	89484C	
GS3	V97U0261C	SEC**-1	F	S	M	C	G4.8	00	ZFI	89484C	
GS4	V97U0262C	SEC**-1	F	S	M	C	G4.8	00	ZFI	89484C	
HS01	V97U0294C	FT	F	S	D	C	G4.8	00	ZFI	89484C	
HS02	V97U0295C	FT	F	S	D	C	G4.8	00	ZFI	89484C	
HS03	V97U0296C	FT	F	S	D	C	G4.8	00	ZFI	89484C	
HS11	V97U0297C	SEC	F	S	D	C	G4.8	00	ZFI	89484C	
HS13	V97U0298C	SEC	F	S	D	C	G4.8	00	ZFI	89484C	
HSMIN	V97U0293C	FT	F	S	D	C	G4.8	00	ZFI	89484C	
L0DMIN	V97U0316C	ND	F	S	D	C	G4.8	00	ZFI	89484C	
NALP	V97U0321C	ND	F	S	D	X	G4.8	00	ZFI	89484C	
NALP1	V99U7402C	ND	I	S	M	C	G4.8	00	ZFI	89484C	
NALP2	V99U7403C	ND	I	S	M	C	G4.8	00	ZFI	89484C	
NDRGCN	V97U9524C	ND	I	S	M	P	G4.8	00	GLE	90152D	
PREBNK	V97U0349C	DEG	F	S	M	C	G4.8	00	ZFI	89484C	
RDMAX	V97U0535C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
RDOTPO	V97U9515C	FT/SEC	F	S	M	P	G4.8	00	GLE	90152D	
RLCMIN	V99U6985C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC1	V97U0470C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC2	V97U0471C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC3	V97U0472C	DEG*SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC4	V97U0473C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC5	V97U0474C	DEG*SEC/FT	F	S	D	C	G4.8	00	ZFI	89484C	
RLMC6	V97U0475C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
ROLLIM	V97U9525C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
ROLLMIN	V99U6986C	DEG	F	S	D	C	G4.8	00	ZFI	89484C	
ROLMN1	V97U9506C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
ROLMN2	V97U9507C	DEG	F	S	M	P	G4.8	00	GLE	90152D	
RPT1	V97U0392C	NMI	F	S	M	C	G4.8	00	GDE	89484C	
RTBFAC	V97U9526C	ND	F	S	M	P	G4.8	00	GLE	90152D	
VA	V97U0421C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VA1	V97U0428C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VA2	V97U0429C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALMOD	V97U0513C	FT/SEC	F	S	M	C	G4.8	00	ZFI	89484C	
VALP(1)	V97U0422C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(10)	V99U7394C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(11)	V99U7395C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(12)	V99U7396C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(2)	V97U0423C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(3)	V97U0424C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(4)	V97U0425C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(5)	V97U0426C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(6)	V97U0427C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(7)	V97U0488C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(8)	V97U0489C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALP(9)	V97U0490C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	

TABLE 4.5.4-3. ENTRY GUIDANCE (G4.8) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
VALPD1	V99U7398C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALPD2	V99U7399C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALPD3 (1)	V99U6981C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VALPD3 (2)	V99U6982C	ND	F	S	M	C	G4.8	00	GDE	89484C	
VALPD3 (3)	V99U6983C	SEC/FT	F	S	M	C	G4.8	00	GDE	89484C	
VALPD3 (4)	V99U6984C	SEC**2/FT**2	F	S	M	C	G4.8	00	GDE	89484C	
VALPMX	V97U9527C	FT/SEC	F	S	M	P	G4.8	00	GLE	90152D	
VB1	V97U0430C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VC16	V97U0432C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VC20	V97U0514C	FT/SEC	F	S	M	C	G4.8	00	ZFI	89484C	
VELMN	V97U0433C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VEROLC	V97U0434C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VERTACLIM	V99U6336C	FT/SEC**2	F	S	M	P	G4.8	00	PTI	DC0599	
VHS1	V97U0435C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VHS2	V97U0436C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VI_ALP_HI	V97U2022C	FT/SEC	F	S	M	P	G4.8	00	GLE	92671A	
VI_ALP_LO	V97U2021C	FT/SEC	F	S	M	P	G4.8	00	GLE	92671A	
VNOALP	V97U0515C	FT/SEC	F	S	M	C	G4.8	00	ZFI	89484C	
VNOALP2	V99U7401C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VQ	V97U0437C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VRDT	V97U0438C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VRLMC	V97U0476C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
VS1	V97U0440C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VTRAN	V97U0441C	FT/SEC	F	S	M	C	G4.8	00	GDE	89484C	
VTURN1	V97U9528C	ND	F	S	M	P	G4.8	00	GLE	90152D	
VTURN2	V97U9529C	FT/SEC	F	S	M	P	G4.8	00	GLE	90152D	
VYLMAX	V97U0442C	FT/SEC	F	S	D	C	G4.8	00	ZFI	89484C	
Y1	V97U0467C	RAD	F	S	D	C	G4.8	00	ZFI	93090E	
							G5.27				
Y2	V97U0468C	RAD	F	S	D	C	G4.8	00	ZFI	89484C	
Y3	V97U0478C	RAD	F	S	D	C	G4.8	00	ZFI	93090E	
							G5.27				
YLMIN	V97U0465C	RAD	F	S	D	C	G4.8	00	ZFI	89484C	
YLMN2	V97U0466C	RAD	F	S	D	C	G4.8	00	ZFI	89484C	
ZK1	V97U0469C	SEC	F	S	D	C	G4.8	00	ZFI	89484C	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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TABLE 4.5.4-4. ENTRY GUIDANCE (G4.8) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
E1	V97U0228C	00	+1.0	E-02 FT/SEC**2	F	S	C	G4.8	29685A	
VSAT	V97U0439C	00	+2.5766200	E+04 FT/SEC	F	S	C	G4.150 G4.8	29685A	
V_TAEM	V97U0420C	00	+2.5000	E+03 FT/SEC	F	S	X	G3.3.19 G4.8	89661A	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.5.4-5. ENTRY GUIDANCE (G4.8) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S	C A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DTEGD ENTRY GUIDANCE CYCLE INTERVAL	V97U6100C	00	+1.92	E+00	SEC	F	S	P G4.8	90881A	

TABLE 4.5.4-5. ENTRY GUIDANCE (G4.8) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S P	A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
NAUTMI_PER_FT FEET TO NAUTICAL MILES CONVERSION FACTOR	V97U5423C	00	+1.6457884	E-04 NMI/FT	F		S C	A6.9 G4.127 G4.144 G4.158 G4.19 G4.20 G4.205 G4.21 G4.210 G4.211 G4.220 G4.23 G4.237 G4.24 G4.25 G4.8 G5.27	93090E	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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4.6 TERMINAL AREA ENERGY MANAGEMENT (MAJOR MODE 305)

4.6.1 Requirements Overview

This phase contains those software functions required to guide the orbiter from the entry interface to the approach and landing (A/L) capture zone. At the A/L interface, a flag is issued to MSC indicating completion of the TAEM guidance phase.

Glide range is controlled by flying to a nominal altitude and dynamic pressure reference versus range profile which can be interpreted as an energy over weight versus range profile. Energy control is achieved by nulling out altitude errors via the normal acceleration command and also by nulling out energy errors when subsonic via the speed brake deflection command. Additional energy control is achieved by limiting the normal acceleration command based on an energy corridor formulated from a nominal energy versus range profile. Also, the normal acceleration command is constrained by limits based on dynamic pressure to inhibit the vehicle from attaining excessively high dynamic pressures or to optimize the vehicle's lift-to-drag ratio during range "stretch" maneuvers. If considerable excess energy exists, an S-turn maneuver is executed to dissipate additional energy. If the vehicle is faced with an extreme low-energy situation, the guidance software sends out a flag, MEPALERT, to displays, which requests that the crew switch the heading alignment cone (HAC) to the minimum entry point (MEP) HAC location. Crew action is required to achieve relocation of the HAC.

At either the nominal or minimum entry point HAC location, the crew can toggle for the straight-in (STRT) or the overhead (OVHD) HAC for weather avoidance. An automatic toggling in the navigation occurs at the crossing of the runway centerline (except during the TAEM guidance heading alignment phase, IPHASE = 2) when in the straight-in mode so that the STRT mode is maintained. Also, if a low energy condition is encountered when in the overhead mode, a signal, OHALRT, is sent to the crew. The OHALRT signal will go off when the energy state becomes satisfactory with respect to a calculated energy versus range reference. The navigation resets the HAC turn angle, PSHA, to an initialization value, PSHARS, when the HAC is toggled, except for toggling at the crossing of the runway centerline.

The inertial navigation and air data subsystems provide input data to the TAEM guidance software. A ground track predictor routine estimates the ground track distance to runway threshold. This range prediction is used to determine the altitude, altitude rate, and dynamic pressure references.

For all guidance phases (S-turn, acquisition, heading alignment, and prefinal), the normal acceleration command is driven by an error signal based on the reference altitude and altitude rate errors. The speed brake command is generated from energy and energy rate errors during subsonic flight, while during supersonic flight, the speed brake command is a constant angle of deflection. Additionally, an altitude dependent blending function is employed during closed-loop speedbrake command operations to enable a functional transition from explicit energy over weight to dynamic pressure errors to ensure compatibility with A/L speedbrake operations at the A/L interface.

On the lateral axis, if the guidance is in the S-turn phase, a constant and Mach dependent roll angle command is input to the flight control system. If the guidance is in the acquisition phase, a roll angle command is given that is proportional to the orbiter heading deviation from tangency to the selected heading alignment cone; the HAC's are used for a final turn to align the orbiter to the runway. In the heading alignment phase, the roll angle command is generated to assure that the orbiter performs a turn which follows the heading alignment spiral. The spiral is the ground plane projection of the cone.

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In the prefinal approach phase, the roll angle command is generated from a linear combination of orbiter lateral deviation and deviation rate from the runway centerline.

Finally, the roll command is limited during all TAEM subphases so that the guidance NZ command plus the flight control, nose-up compensation, NZ command does not exceed a vehicle and weight dependent normal load limit.

An exception to nominal glide range and ground track control operations is the bailout abort mode. Due to an emergency situation, the crew may elect to bail out from the vehicle prior to landing. In order to support this contingency egress condition, software functions are provided that enable the guidance to be configured for bailout commands. Once subsonic, the crew may invoke the bailout mode by first engaging the abort PBI with the abort mode select switch set to ATO. This action will cause the guidance to inhibit any subsequent transition to approach/land, will cause the speed brake to be commanded to retract, and will disable lateral ground track control commands after CSS roll/yaw is engaged. Once the crew has manually established the desired airspeed and roll attitude conditions for bailout, moding the pitch and bank FCS channels to auto will complete the engagement of the bailout mode and cause the guidance to issue normal acceleration and roll commands that maintain these desired conditions. These bailout commands may be terminated by resuming manual (i.e., CSS) mode operations, whereupon the normal acceleration function will revert back to nominal glide range dependent operations although lateral ground track control commands will remain disabled. Reengagement of automode will then again engage the bailout mode. A status indicator for the bailout mode is provided on the Vert Sit display and is driven by bailout dependent discretized output by the guidance.

The flight control system (FCS) provides the interface between the guidance system and the orbiter aerodynamic control surfaces. The inputs from the guidance system to the FCS are (1) normal load factor command, (2) speed brake command, and (3) roll angle command. The commanded load factor is achieved by operating the elevons symmetrically using normal acceleration and pitch rate feedback in the FCS. The speed brake is operated directly by the speed brake servos in the FCS. The roll angle command is achieved by operating the elevons differentially using roll attitude and roll rate feedback in the FCS. The body flap is controlled by the autopilot to maintain elevon trim.

Figure 3.1-2 shows typical target loci for the entry-TAEM interface.

4.6.2 Terminal Area Energy Management Guidance (G4.9)

All phases of TAEM guidance are defined in this document. A wide variety of initial conditions and disturbances must be accommodated by the guidance, including variations in range and approach azimuth, altitude dispersions, wind profiles of various shapes and intensities, and turbulence. It is intended to handle off-nominal cases to the extent of the vehicle's capability to maneuver. Therefore, maximum flexibility has been designed into the software.

4.6.2.1 Software Requirements Summary.

The following subsections (4.6.2.2 through 4.6.2.12) define the detailed software requirements for the several functions and subfunctions that constitute the TAEM guidance program. Each function or subfunction is described in five subheadings:

- A. Detailed Requirements. The equations (in HAL language) and logic performed by the function.
- B. Interface Requirements. The input/output parameters and I-loads/constants for each software function within TAEM guidance are shown in each subsection describing the function. Equivalent internal input names are shown in Table 4.6.2.1-1 in conjunction with the following detailed requirements.
- C. Processing Requirements. Processing frequency, guidance phase limits, position in function execution sequence, etc. All arithmetic computations are to be done single precision.
- D. Initialization Requirements. Any flags or variables that must be initialized prior to first execution of the function.
- E. Supplemental Information. Any additional information that aids in understanding the function.

The functions and subfunctions of TAEM guidance are:

- TAEM guidance (TGEXEC)
- TAEM guidance initialization(TGINIT)
- XHAC function (TGXHAC)
- Ground track predictor (GTP)
- Resolve to 180 degrees routine (RES180)
- References, dynamic pressure, and spiral adjust function (TGCOMP)
- Phase transition, MEP, and OHALRT function (TGTRAN)
- Normal acceleration command function (TGNZC)
- Speed brake command function (TGSBC)
- Roll command function (TGPHIC)

Table 4.6.2.1-1. TAEM Guidance Input/Internal Name Equivalence				
MSID	Source Input Name	Guidance Internal Name	Description	Source
V90U1961CC	M	MASS	Current vehicle mass	DEORB GUID
V95H0220CC	POSITION_WRT_RUNWAY(1)	X	Downrange distance wrt RW	TAEM UPP
V95H0221CC	POSITION_WRT_RUNWAY(2)	Y	Crossrange distance wrt RW	TAEM UPP
V95L0255CA	VELOCITY_WRT_RUNWAY(1)	XDOT	Downrange vel wrt RW	TAEM UPP
V95L0256CB	VELOCITY_WRT_RUNWAY(2)	YDOT	Crossrange vel wrt RW	TAEM UPP
V95H0225CB	COURSE_WRT_RW	PSD	Course (heading) wrt RW center line	TAEM UPP
V95L0151CD	REL_VEL_MAG	V	Ground rel vel magnitude	TAEM UPP
V95H0261CA	FLT_PATH_ANG	GAMMA	Ground rel flight path angle	TAEM UPP
V95L0265CB	H_DOT_ELLIPSOID	HDOT	Estimated altitude rate	TAEM UPP
V95L0178CC	V_GROUNDSPEED	VH	Groundspeed	TAEM UPP
V95H0165CC	ALT_WHEELS	H	Alt to rear wheels	TAEM UPP
V95U0205CB	RW_ID_UPP	RW_ID	Index of current RW	TAEM UPP
V90H2215C	COSTH	COSTH	Euler angle pitch cosine	A/E ATT PROC
V90H2204C	COSPHI	COSPHI	Euler angle roll cosine	A/E ATT PROC
V95P3170C	QBAR_N	QBAR_N	Nav derived dynamic pressure	NAVDAD SOP
V95P3011C	QBAR	QBAR_AD	GN&C dynamic pressure	ADTA SOP
V95L3029C	M	MACH	GN&C Mach number	ADTA SOP
V95X3148X	DEF_AD	DEF_AD	Default air data flag	ADTA SOP
V93X4466X	NEP	NEP	Entry point switch cmd (a.k.a. Nominal Entry Point flag)	HORIZ SIT DISP
V93X4476X	GI_CHANGE	GI_CHANGE	Head wind high/low cmd (a.k.a. steep glideslope ground intercept redesignation flag)	HORIZ SIT DISP
V95U0183CA	R_NEP	RTURN	HAC radius	ENTRY UPP
V95H0181CC	PSHA	PSHA	Turn angle HAC	ENTRY UPP
V95H0181CA	PSHA	PSHA	Turn angle HAC	TAEM UPP
V95J0153CB	YSGNP	YSGN	R/L cone ind	TAEM UPP
V95A0170CD	ACC_VERT	ACC_VERT	Topodetic vertical accel	TAEM UPP
V90X1632XA	AUTOP_LAMP	AUTOP_LAMP	Pitch axis auto indiactor	AEROJET DAP
V90X1642XA	AUTORY_LAMP	AUTORY_LAMP	Roll/yaw axis auto indicator	AEROJET DAP
V90X8654X	BAILOUT_FLAG	BAILOUT_FLAG	Bailout request flag	MSC
V90H2202C	PHI	PHI	Body roll attitude Euler angle	A/E ATT PROC
V95H3021C	ALPHA	ALPHA	GN&C angle of attack	ADTA SOP
V90R5321CA	Q_ORB	Q	Selected RGA Pitch Rate	SF
V95A0160CC	ACC_DRAG	ACC_DRAG	Drag deceleration	TAEM UPP

4.6.2.2 TAEM Guidance (TGEXEC).

This function is the TAEM guidance executive routine.

A. Detailed Requirements. On the first pass (i.e., INIT_PASS = FALSE) or whenever the runway index is changed (RW_ID ≠ RW_IDO), the initialization function (TGINIT) is executed first. Next the XHAC (TGXHAC) and the ground track predictor (GTP) functions are called. The TAEM reference and dynamic pressure function (TGCOMP) is then executed. The TAEM phase transition and MEP function (TGTRAN) is then called. The guidance commands are then generated by calling the normal acceleration command (TGNZC), the speed brake command (TGSBC), and the roll command (TGPHIC) functions. TAEM guidance is then exited.

B. Interface Requirements. The input and output parameters are listed in Table 4.6.2.2-1. No I-loads/constants are identified.

C. Processing Requirements. The TGEXEC function is executed at the TAEM guidance rate during the entire TAEM major mode.

D. Initialization Requirements. The TAEM guidance initialization flag, INIT_PASS, must be initialized to 'FALSE' before the first entry into TGEXEC.

E. Supplemental Information. The following functions are called by TGEXEC: TGINIT, TGXHAC, GTP, TGCOMP, TGTRAN, TGNZC, TGSBC, and TGPHIC.

Table 4.6.2.2-1. TGEXEC Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
INIT_PASS	TAEM guidance first-pass flag	TGINIT	ND	D
RW_ID	Index of current runway	NAV	ND	I
RW_IDO	Past value of runway index	TGINIT	ND	I
OUTPUTS				
INIT_PASS	TAEM guidance first-pass flag	TGINIT	ND	D

4.6.2.3 TAEM Guidance Initialization (TGINIT).

A. Detailed Requirements. The TGINIT function initializes or computes several parameters used in TAEM guidance. These operations are contained in Equation Set TGINIT.

Equation Set TGINIT

INIT_PASS = TRUE

ISR = RFTC/DTG

MEPALERT = FALSE

RF = RFO

PHILIM = PHILM1

DNZUL = DNZUC1

DNZLL = DNZLC1

QBARF = QBAR_AD

QBD = 0.0

IPHASE = 1

TG_END = FALSE

RW_IDO = RW_ID

AUTOP_LAMP_PAST = AUTOP_LAMP

AUTORY_LAMP_PAST = AUTORY_LAMP

IGS = 1

If MASS > WT_GS1, then IGS = 2

DEF_ADO = DEF_AD

V_PAST = V

If DEF_AD = TRUE and V > V_DEF, then QBARF = QBAR_N

GMAX = MIDVAL (GMAXS MASS + GMAXB, GMAXLL, GMAXUL)

B. Interface Requirements. The input and output parameters for TGINIT are listed in Table 4.6.2.3–1. The I-loads/constants used in TGINIT are listed in Table 4.6.2.3–2.

C. Processing Requirements. TGINIT is executed on the initial execution cycle of TAEM guidance or whenever RW_ID ≠ RW_IDO (redesignation) and should be executed before any other TAEM guidance function whenever this criterion is satisfied.

D. Initialization Requirements. None.

E. Supplemental Information. If an air data system fails, two alternate sources of dynamic pressure will be available to TAEM guidance. The first is a default dynamic pressure scheduled as a function of velocity and is output by the ADTA SOP when the flag DEF_AD = TRUE. The second is an estimated dynamic pressure derived from the navigated altitude and velocity. When default dynamic pressure is being supplied by the ADTA SOP and $V > V_DEF$, the NAV-derived dynamic pressure is used in calculating NZ limits. In all other instances, the ADTA SOP output is used for NZ limits. When DEF_AD = TRUE, dynamic pressure derived speed brake commands are based on NAV-derived dynamic pressure.

The ability to accommodate multiple glide slopes in TAEM is self-contained in the guidance and is presently a function of weight only. The determination of glide slope and reference constants will be made consistent with approach and landing references and operations

Table 4.6.2.3-1. TGINIT Input/Output Parameters				
Name	Description	Source or Destination	Units	Type
INPUTS				
INIT_PASS	TAEM guidance first-pass flag	TGEXEC	ND	D
V	Ground relative velocity magnitude	NAV	ft/sec	F
AUTOP_LAMP	Auto lamp status, pitch axis	AEROJET DAP	ND	D
AUTORY_LAMP	Auto lamp status, roll/yaw axis	AEROJET DAP	ND	D
MASS	Current vehicle mass	DEORB GUID	slugs	F
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
QBAR_N	NAV derived dynamic pressure	NAVDAD SOP	psf	F
RW_ID	Target runway index number	NAV	ND	I
DEF_AD	Default air data flag	ADTA SOP	ND	D
OUTPUTS				
INIT_PASS	TAEM guidance first-pass flag	TGEXEC	ND	D
MEPALERT	MEP alert status	GAX, TLM	ND	D
ISR	Prefinal roll command fader counter	TGPHIC	ND	I
PHILIM	TAEM phase dependent roll command limit	TGPHIC	deg	F
DNZUL	Upper limit on normal acceleration command	TGNZC	g	F
DNZLL	Lower limit on normal acceleration command	TGNZC	g	F
QBARF	Filtered dynamic pressure	TGCOMP	psf	F
QBD	Filtered dynamic pressure rate	TGCOMP	psf/sec	F
IPHASE	TAEM phase counter	TGTRAN, TGNZC, TGSBC, TGPHIC, TGCOMP, GTP, TLM, NAV, ENT AREA NAV, VERT SIT DIP, HUD PROC, HORIZ SIT SPEC, E/L ADI PROC, MEDS FC GNC XFER	ND	I

Table 4.6.2.3-1. TGINIT Input/Output Parameters				
Name	Description	Source or Destination	Units	Type
TG_END	TAEM guidance termination flag	MSC, AEROJET DAP, E/L ADI PROC, VERT SIT DIP, HORIZ SIT SPEC, SPI PROC, VERT SIT 2, TLM, HUD PROC, NAV, MEDS FC GNC XFER, GN&C/ SM-PL IF	ND	D
RW_IDO	Past value of RW_ID	TGEXEC	ND	I
IGS	Glide slope index	TGCOMP, TGSBC, TGTRAN, TGNZC, TGXHAC, VERT SIT DIP, HUD PROC, TLM	ND	I
AUTOP_ LAMP_PAST	Past value of auto lamp status, pitch axis	TGTRAN	ND	D
AUTORY_ LAMP_PAST	Past value of auto lamp status, roll/yaw axis	TGTRAN	ND	D
DEF_ADO	Past value of DEF_AD	TGCOMP	ND	D
V_PAST	Past value of V	TGCOMP	ft/sec	F
RF	HAC radius at PSHA = 0°	GTP, TGCOMP, HORIZ SIT SPEC	ft	F
GMAX	Maximum normal load limit	TGPHIC	g	F

Table 4.6.2.3-2. TGINIT I-Loads / Constants					
MSID No.	Name	Description	Value	Units	Class
V97U6116C	DTG	Time step between TAEM guidance calls	0.96	sec	X
V97U0385C	RFTC	Roll fader time constant		sec	SX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX
V97U0124C	DNZLC1	Phase 0, 1, and 2 NZC lower limit		g	SX
V97U0126C	DNZUC1	Phase 0, 1, and 2 NZC upper limit		g	SX
V97U0444C	WT_GS1	Mass for glide slope determination		slugs	MX
V97U0536C	V_DEF	NAVDAD/default Qbar switch velocity		ft/sec	MX
V96U8262C	RFO	Nominal HAC radius at PSHA = 0°		ft	SX
V97U0166C	GMAXB	GMAX bias		g	MX
V97U0172C	GMAXS	GMAX slope		g/slug	MX
V97U0179C	GMAXLL	GMAX lower limit		g	MX
V97U0180C	GMAXUL	GMAX upper limit		g	MX

4.6.2.4 XHAC Function (TGXHAC).

This function determines the ground intercept index (IGI), the X location of the nominal and MEP HAC centers, the HAC location depending on the NEP discrete, and the prefinal initiation range value (RPRED3).

A. Detailed Formulation. The ground intercept index, IGI, is set according to the value of the GI_CHANGE discrete, as shown in Equation Set 1.

$$1.1 \quad \text{IGI} = 1$$

$$1.2 \quad \text{If GI_CHANGE} = \text{TRUE, then IGI} = 2$$

The nominal and MEP HAC X positions, XFTC and XMEP (and the trajectory reference point XALI), are calculated as shown in Equation Set 2.

$$2.1 \quad \text{XFTC} = \text{XA}_{\text{IGI}} + \text{HFTC}_{\text{IGS}}/\text{TGGS}_{\text{IGS}}$$

$$2.2 \quad \text{XALI} = \text{XA}_{\text{IGI}} + \text{HALI}_{\text{IGS}}/\text{TGGS}_{\text{IGS}}$$

$$2.3 \quad \text{XMEP} = \text{XA}_{\text{IGI}} + \text{HMEP}_{\text{IGS}}/\text{TGGS}_{\text{IGS}}$$

The HAC X position, XHAC, based on the nominal entry point discrete, NEP, and the prefinal initiation range value, RPRED3, are calculated as shown in Equation Set 3.

$$3.1 \quad \text{XHAC} = \text{XFTC}$$

$$3.2 \quad \text{If NEP} = \text{OFF, then XHAC} = \text{XMEP}$$

$$3.3 \quad \text{RPRED3} = -\text{XHAC} + \text{DR3}$$

Finally, the NEP/MEP feedback discrete for displays, NEP_FB, is set to the NEP value (i.e., NEP_FB = NEP).

B. Interface Requirements. The input/output parameters for TGXHAC are listed in Table 4.6.2.4-1. The I-loads are listed in Table 4.6.2.4-2.

C. Processing Requirements. TGXHAC is processed at the TAEM guidance rate.

D. Initialization Requirements. None.

Table 4.6.2.4-1. TGXHAC Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
GI_CHANGE	Steep glideslope ground intercept redesignation flag	HORIZ SIT DISP	ND	D
NEP	Nominal Entry Point flag	HORIZ SIT DISP	ND	D
IGS	Glide slope index	TGINIT	ND	I
OUTPUTS				
XALI	Trajectory reference point	TGCOMP	ft	F
XHAC	X (r.w.) coordinate of HAC center	GTP, HORIZ SIT SPEC	ft	F
RPRED3	Prefinal initiation range value	TGTRAN	ft	F
NEP_FB	NEP/MEP flag	E/L ADI PROC, HORIZ SIT SPEC, TLM	ND	D
IGI	Ground intercept index	HUD PROC	ND	I

Table 4.6.2.4-2. TGXHAC I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0136C	DR3	Delta range value for RPRED3		ft	SX
V97U0287C	HALI(I)*	Altitude to determine XALI		ft	SX
V97U0288C					
V97U0291C	HFTC(I)*	Altitude to determine XFTC		ft	SX
V97U0292C					
V97U0414C	TGGS(I)*	Tangent of Autoland steep glide slope		ND	MX
V97U0415C					
V97U0456C	XA(I)*	Steep glide slope X intercept		ft	MX
V97U0457C					
V96U8636C	HMEP(I)*	Altitude to determine XMEP		ft	SX
V96U8637C					
*I = 1,2					

4.6.2.5 Ground Track Computation (GTP).

This section describes the equations used by the ground track predictor subprogram in mathematical symbols. The detailed formulation of the ground track predictor subprogram is given in Section 4.6.2.5.A.

An essential part of the TAEM guidance concept is the prediction of ground track range to runway threshold. The method for computing ground track range is illustrated in Figure 4.6.2.5-1. As shown, the orbiter velocity vector is initially pointing away from tangency to the heading alignment cone (spiral in ground plane). The acquisition turn is defined as the turn that will align the orbiter heading tangent to the heading alignment cone. The distance, d_{AC} , along the acquisition turn is computed from geometrical equations and an estimate of the acquisition turn radius. The distance d_1 is computed from geometrical equations relating the position of the orbiter after the acquisition turn to the tangent point on the alignment cone. The distance in the heading alignment turn is computed from the turn angle in the heading alignment phase and the alignment spiral radius. The distance d_T is a fixed distance from runway threshold for each of two possible downrange locations of the alignment cones. The two possible downrange locations of the alignment cones are referred to as the nominal and minimum entry point (MEP) locations. The two possible cross ranges with respect to the runway locations of the heading alignment cones are referred to as the straight-in and overhead HAC locations.

The ground track predictor estimates range-to-go by computing the segments d_{AC} , d_1 , d_{HAC} , and d_T . These segments are added to give the total predicted range. The terms that no longer apply as the approach progresses are either set to zero or dropped from the summations.

No additional range component is required for the S-turn phase because the predicted ground track during this phase is computed as if the S-turn were to cease immediately.

During Phase 3 (prefinal approach), and after the vehicle's downrange position with respect to the runway is within predetermined value with respect to the HAC, the estimated range-to-go is based on a straight line to the runway threshold, thus

$$R_{\text{PRED}} = \sqrt{X^2 + Y^2}$$

The geometry for computing the segments d_{AC} and d_1 is given in Figure 4.6.2.5-2. The angle $\Delta \psi$ is the difference between the orbiter heading, ψ , and the heading, ψ_T , to the heading alignment cone tangency point. The heading alignment cone is a spiral in the ground plane described by:

$R_{\text{TURN}} = R_1 + R_1 \psi_{HA} + R_2 \psi_{HA}^2$. Given an estimate of ψ_{HA} , the spiral acquisition is simplified by assuming a circle with center at R_F and radius of R_{TURN} . The vector from the orbiter to the center of the selected heading alignment cone is computed as

$$X_{\text{CIR}} = X_{\text{HAC}} - X$$

$$Y_{\text{CIR}} = Y_{\text{SGN } R_F} - Y$$

The distance to the center of the heading alignment cone is

$$R_{\text{CIR}} = \sqrt{(X_{\text{CIR}})^2 + (Y_{\text{CIR}})^2}$$

and the straight line distance to the tangency point is

$$R_{TAN} = \sqrt{(R_{CIR})^2 - (R_{TURN})^2}$$

which is then limited so that $R_{TAN} > 0$.

The heading, ψ_C , to the center of the heading alignment cone is given by

$$\psi_C = \tan^{-1}(Y_{CIR}/X_{CIR})$$

The heading to the tangency point is then

$$\psi_T = \psi_C - YSGN \tan^{-1}(R_{TURN}/R_{TAN})$$

and the heading error is

$$\Delta\psi = \psi_T - \psi$$

An acquisition turn radius is computed as a function of a predicted average roll angle during the turn. The turn radius, R_{AC} , and the error angle, $\Delta\psi$, are used to compute the distance, d_{AC} , to be traveled during acquisition. The distance, d_1 , to the tangency point from the end of acquisition is computed by using $\Delta\psi$, R_{AC} , and R_{TAN} .

The radius of the acquisition turn, R_{AC} , is approximated by

$$R_{AC} = V_h V / (g \tan(\phi_{avg}))$$

where

V_h = horizontal velocity

ϕ_{AVG} = predicted average roll angle

V = velocity magnitude

The acquisition turn arc is

$$d_{AC} = R_{AC} | \Delta\psi |$$

The distance, d_1 , is derived from the geometry of Figure 4.6.2.5-2.

$$A = R_{AC} (1. - \cos(\Delta\psi))$$

$$B = R_{TAN} - R_{AC} | \sin(\Delta\psi) |$$

$$d_1 = \sqrt{A^2 + B^2}$$

A. Detailed Requirements. On each execution cycle of GTP, the vehicle's runway relative downrange position with respect to the HAC center is computed as $XCIR = XHAC - X$.

If $IPHASE = 3$ and $XCIR < DR4$, then $RPRED = \text{SQRT}(X^2 + Y^2)$ and then exit GTP. Otherwise ($IPHASE \neq 3$ or $XCIR \geq DR4$), the remaining GTP logic is processed.

First execute Equation Set 1:

- 1.1 $SIGNY = SIGN(Y)$
- 1.2 $YCIR = YSGN RF - Y$
- 1.3 $RCIR = SQRT(XCIR^2 + YCIR^2)$
- 1.4 If $RCIR > RTURN$, then $RTAN = SQRT(RCIR^2 - RTURN^2)$, else $RTAN = 0.0$

The heading error (from a heading tangent to the HAC), HAC turn angle, spiral turn radius, and range from HAC to runway are then computed by Equation Set 2:

- 2.1 $PSC = ARCTAN2(YCIR, XCIR)$
- 2.2 $PST = (PSC - YSGN ARCTAN2(RTURN, RTAN)) DEG_PER_RAD$
- 2.3 $PST = RES180(PST)$
- 2.4 $DPSAC = RES180(PST - PSD)$

The absolute value of the heading error, DPSAC, will be passed to the MEDS FC GNC XFER for the purpose of digital display on the MEDS composite flight instrument display.

$$2.4.1 \quad MEDS_DPSAC = ABS(DPSAC)$$

In order to correctly calculate the HAC turn angle, PSHA, under all possible situations, a test is included which monitors the HAC turn angle input from navigation to check for an OVHD/STRT toggling condition or runway change. Under those situations, the navigation resets the HAC turn angle to an initialization value, PSHARS.

- 2.5 $PSHAN = -PST YSGN$
- 2.6 If $((PSHA > PSHARS + 1$ or $PSHAN < -1.0$ or $YSGN \neq SIGNY)$ and $PSHA > 90.$), then $PSHAN = PSHAN + 360.$
- 2.7 $PSHA = PSHAN$
- 2.8 $RTURN = RF + R1 PSHA + R2 PSHA^2$
- 2.9 $RPRED2 = (RF PSHA + 0.5 R1 PSHA^2 + 0.333333 R2 PSHA^3) RAD_PER_DEG - XHAC$

If $IPHASE < 2$, the acquisition turn radius and arc length are then computed in Equation Set 3:

- 3.1 $PHAVG = PHAVGC - PHAVGS MACH$
- 3.2 $PHAVG = MIDVAL(PHAVG, PHAVGLL, PHAVGUL)$
- 3.3 $RTAC = VH V / (GO TAN(PHAVG RAD_PER_DEG))$
- 3.4 $ARCAC = RTAC ABS(DPSAC) RAD_PER_DEG$

IF $IPHASE < 2$, the range from the end of the acquisition turn to the HAC tangency point, RC, as well as the total range to HAC interception, RTAN, are next computed by Equation Set 4:

$$4.1 \quad A = RTAC (1. - \text{COS}(\text{DPSAC RAD_PER_DEG}))$$

$$4.2 \quad B = RTAN - RTAC \text{ ABS}(\text{SIN}(\text{DPSAC RAD_PER_DEG}))$$

$$4.3 \quad RC = \text{SQRT}(A^2 + B^2)$$

$$4.4 \quad RTAN = \text{ARCCAC} + RC$$

Finally, the total range-to-go is calculated from $RPRED = RPRED2 + RTAN$, and GTP is then exited.

B. Interface Requirements. The input/output parameters for GTP are shown in Table 4.6.2.5-1. The I-loads/constants used in GTP are shown in Table 4.6.2.5-2.

C. Processing Requirements. GTP is processed at the TAEM guidance rate when called by TGEXEC.

D. Initialization Requirements. None.

E. Supplemental Information. The following function is called by GTP: RES180.

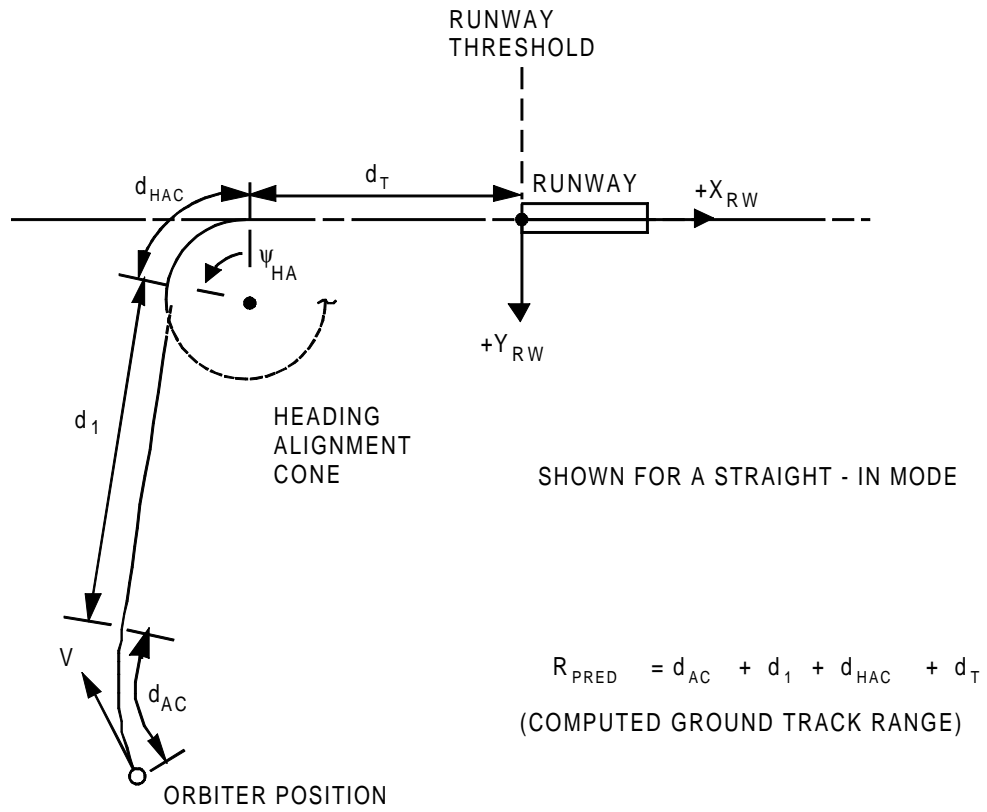


FIGURE 4.6.2.5-1. TAEM Guidance Ground Track Predictor Geometry

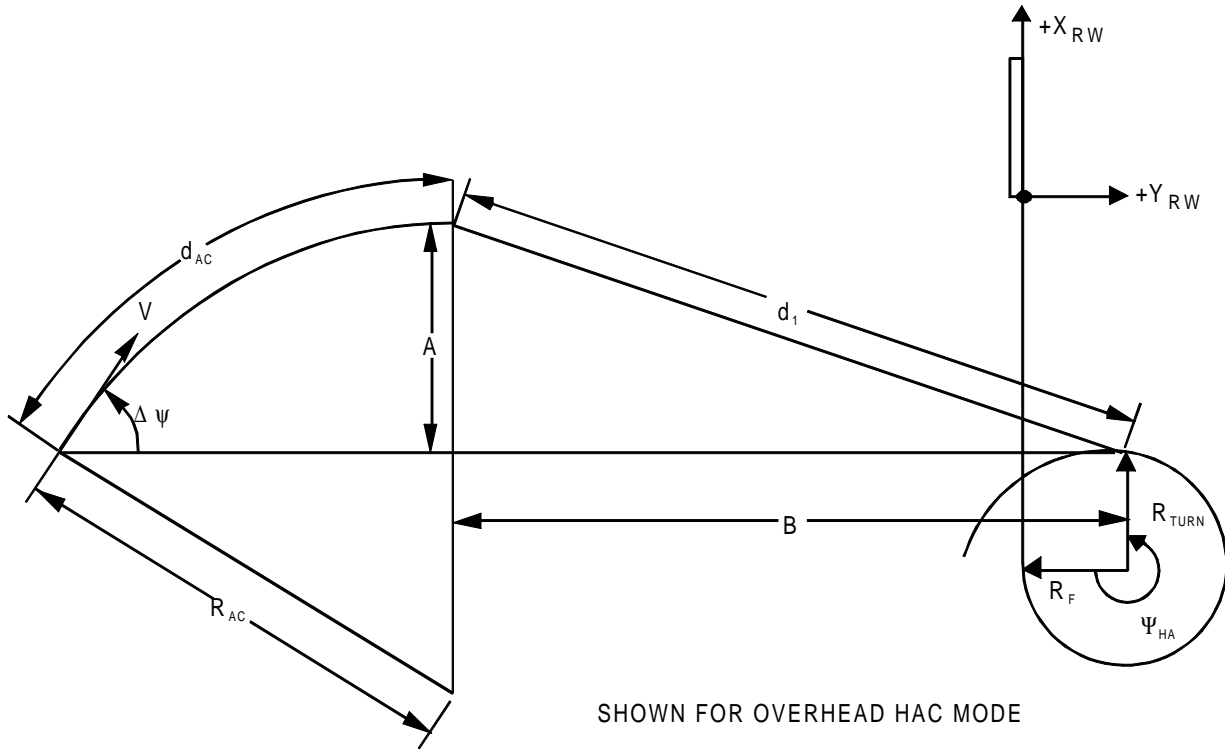


FIGURE 4.6.2.5-2. GTP Geometry for Acquisition Phase

Table 4.6.2.5-1. GTP Input/Output Parameters				
Name	Description	Source or Destination	Units	Type
INPUTS				
MACH	Mach number	ADTA SOP	ND	F
X	Downrange position wrt runway	NAV	ft	F
YSGN	Sign of cross range position wrt runway of selected HAC	NAV	ND	F
XHAC	X (r.w.) coordinate of HAC center	TGXHAC	ft	F
Y	Crossrange position wrt runway	NAV	ft	F
PSHA	HAC turn angle	NAV	deg	F
PSD	Heading with respect to runway centerline	NAV	deg	F
RTURN	Spiral turn radius	NAV	ft	F
VH	Horizontal ground speed	NAV	ft/sec	F
RF	HAC radius at PSHA = 0°	TGINIT, TGCOMP	ft	F
V	Ground relative velocity magnitude	NAV	ft/sec	F
IPHASE	Guidance phase indicator	TGINIT, TGTRAN	ND	I
OUTPUTS				
RPRED	Predicted ground track range to the runway threshold	VERT SIT DIP, ENT AREA NAV, HORIZ SIT SPEC, TGCOMP, TGTRAN, TLM	ft	F
XCIR	X–distance to heading alignment cone	TGPHIC	ft	F
YCIR	Y–distance to heading alignment cone	TGPHIC	ft	F
DPSAC	Heading error wrt HAC tangency	TGPHIC, TLM, E/L ADI PROC	deg	F
MEDS_DPSAC	MEDS Display heading error	MEDS FC GNC XFER	deg	F
RCIR	Distance to HAC center	TGTRAN, TGPHIC, ENT AREA NAV	ft	F
PHAVG	Average roll angle during acquisition turn	TLM	deg	F
RPRED2	Range from HAC to runway	TGCOMP, TGNZC	ft	F
PSHA	HAC turn angle	TGCOMP, TGTRAN, TGNZC, TGPHIC, NAV	deg	F

Table 4.6.2.5-1. GTP Input/Output Parameters				
Name	Description	Source or Destination	Units	Type
RTAN	Straight line distance to HAC tangency point	HORIZ SIT SPEC, E/L ADI PROC	ft	F
RTURN	Spiral turn radius	TGTRAN, TGPHIC, HORIZ SIT SPEC, E/L ADI PROC, ENT AREA NAV	ft	F

Table 4.6.2.5-2. GTP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V90A7622C	GO	Earth gravitational constant	32.174049	ft/sec ²	X
V97U0383C	RAD_PER_DEG	Degree to radian factor	0.017453293	rad/deg	X
V97U0112C	DEG_PER_RAD	Radian to degree factor	57.2957795131	deg/rad	X
V97U0335C	PHAVGC	Constant for computing PHAVG		deg	SX
V97U0337C	PHAVGS	Slope for computing PHAVG		deg	SX
V97U0336C	PHAVGLL	Lower limit for PHAVG		deg	SX
V97U0338C	PHAVGUL	Upper limit for PHAVG		deg	SX
V96U8263C	R1	Coefficient of spiral		ft/deg	SX
V96U8264C	R2	Coefficient of spiral		ft/deg ²	SX
V96U8647C	PSHARS	PSHA reset value		deg	SX
V96U8635C	DR4	Distance for HAC for prefinal range		ft	SX

4.6.2.6 TAEM Reference, Dynamic Pressure, and Spiral Adjust Function (TGCOMP).

The TGCOMP function calculates the references for energy over weight, altitude, flight path angle tangent, and dynamic pressure as a function of range to go (RPRED) and steep glide slope selection. The reference energy over weight (EN) may be lowered if it is necessary to target for subsonic conditions at the HAC for an estimated range-to-go at the start of the HAC phase, RPRED2, greater than the maximum range, R2MAX, for subsonic roll maneuvers (MACH < PHIM). The function also computes the vehicle's present energy over weight, altitude error, filtered dynamic pressure, dynamic pressure error, and equivalent airspeed command. The final turn radius, RF, of the HAC spiral is adjusted in the HAC phase as a function of altitude error from an altitude profile, HREFOH, that is lower than the nominal altitude reference. This lower altitude reference corresponds to the altitude profile for a 360-degree overhead HAC. The altitude reference is the Autoland steep glide slope for ranges less than |XALI|. For ranges greater than |XALI|, the reference is a third-order polynomial tangent to the steep glide slope at RPRED = -XALI and is tangent to a constant glide slope at DRPRED = PBRC_{IGS}. If DRPRED is greater than PBRC_{IGS}, this constant glide slope will be used to derive the altitude reference. The flight path angle tangent reference is simply the negative of the derivative of the altitude reference with respect to range. The dynamic pressure reference is a limited linear relationship with range, and the energy over weight references are linear relationships with respect to range involving possible multiple segments.

A. Detailed Requirements. After TGCOMP is entered, the following computations are made:

1. The range to XALI (DRPRED), the vehicle's energy over weight (EOW) and energy over weight reference (EN) are calculated as shown in Equation Set 1. Additionally, the energy over weight references for S-turn initiation (ES), MEPALERT status (EMEP) and NZC limiting (EMAX, EMIN) are also calculated in Equation Set 1.

$$1.1 \quad \text{DRPRED} = \text{RPRED} + \text{XALI}$$

$$1.2 \quad \text{EOW} = \text{H} + \text{V} \text{V}/(2 \text{GO})$$

$$1.3 \quad \text{IEL} = 1$$

$$1.4 \quad \text{If } \text{DRPRED} < \text{EOW_SPT}_{\text{IGS}}, \text{ then } \text{IEL} = 2$$

$$1.5 \quad \text{EN} = \text{EN_C1}_{\text{IGS,IEL}} + (\text{DRPRED}) (\text{EN_C2}_{\text{IGS,IEL}}) \\ - \text{MIDVAL}(\text{EN_C2}_{\text{IGS,1}} (\text{RPRED2} - \text{R2MAX}), 0, \text{ESHFMX})$$

$$1.6 \quad \text{ES} = \text{ES1}_{\text{IGS}} + \text{DRPRED} \text{EDRS}_{\text{IGS}}$$

$$1.7 \quad \text{EMEP} = \text{EMEP_C1}_{\text{IGS,IEL}} + \text{DRPRED} \text{EMEP_C2}_{\text{IGS,IEL}}$$

$$1.8 \quad \text{EMAX} = \text{EN} + \text{EDELNZ}_{\text{IGS}} \text{MIDVAL}(\text{DRPRED}/\text{DEL_R_EMAX}_{\text{IGS}}, \\ \text{EDEL C1}, \text{EDEL C2})$$

$$1.9 \quad \text{EMIN} = \text{EN} - \text{EDELNZ}_{\text{IGS}}$$

2. The altitude reference (HREF), dynamic pressure reference (QBREF), altitude error (HERROR), and flight path angle reference (DHDRRF), and final turn radius of the heading alignment spiral (RF) are calculated as shown in Equation Set 2. If $DRPRED > PBRC_{IGS}$ then Equations 2.1 and 2.2 are replaced by: $HREF = PBHC_{IGS} + PBGC_{IGS} (DRPRED - PBRC_{IGS})$.
- 2.1 $HREF = HAL_{IGS} - TGGS_{IGS} DRPRED$
- 2.2 If $DRPRED > 0$, then $HREF = HREF + DRPRED DRPRED (CUBIC_C3_{IGS} + DRPRED CUBIC_C4_{IGS})$
- 2.3 If $DRPRED \geq PBRCQ_{IGS}$, then $QBREF = MIDVAL(QBRLL_{IGS} + QBC1_{IGS} (DRPRED - PBRCQ_{IGS}), QBRLL_{IGS}, QBRML_{IGS})$
- 2.4 IF $DRPRED < PBRCQ_{IGS}$, then $QBREF = MIDVAL(QBRUL_{IGS} + QBC2_{IGS} DRPRED, QBRLL_{IGS}, QBRUL_{IGS})$
- 2.5 If $IPHASE = 2$ and $PSHA > PSRF$, then execute Equation Set 2.6.
- 2.6.1 $HREFOH = HREF - MIDVAL(DHOH1 (DRPRED - DHOH2), 0, DHOH3)$
- 2.6.2 $DRF = DRFK (HREFOH - H)/(PSHA RAD_PER_DEG)$
- 2.6.3 $RF = MIDVAL(RFMN, RF + DRF, RFMX)$
- 2.7 $HERROR = HREF - H$
- 2.8 $DHDRRF = -PBGC_{IGS}$
- 2.9 If $DRPRED \leq PBRC_{IGS}$, then $DHDRRF = -MIDVAL(-TGGS_{IGS} + DRPRED (2 CUBIC_C3_{IGS} + 3 CUBIC_C4_{IGS} DRPRED), PBGC_{IGS}, -TGGS_{IGS})$
3. The filtered dynamic pressure (QBARF), the filtered dynamic pressure rate (QBD), dynamic pressure error (QBERR), and equivalent airspeed command (EAS_CMD) are calculated as shown in Equation Set 3.

First, the dynamic pressure filter input is selected.

- 3.1 $QBAR = QBAR_AD$
- 3.2 If $DEF_AD = TRUE$ and $V > V_DEF$, then $QBAR = QBAR_N$

Next the filter previous values are reinitialized each time input source switching occurs to avoid false rate transients.

If $(DEF_AD = TRUE$ and $V < V_DEF$ and $V_PAST > V_DEF)$ or $(V < V_DEF$ and $DEF_AD \neq DEF_ADO)$, equations 3.3 and 3.4 are executed.

- 3.3 $QBARF = QBAR$
- 3.4 $QBD = 0$.

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Finally, required past values are updated and all remaining dynamic pressure quantities are calculated using equations 3.5 through 3.12.

$$3.5 \quad \text{DEF_ADO} = \text{DEF_AD}$$

$$3.6 \quad \text{V_PAST} = \text{V}$$

$$3.7 \quad \text{QBARD} = \text{MIDVAL}(\text{CQG} (\text{QBAR} - \text{QBARF}), -\text{QBARDL}, \text{QBARDL})$$

$$3.8 \quad \text{QBARF} = \text{QBARF} + \text{QBARD} \text{ DTG}$$

$$3.9 \quad \text{QBD} = \text{CDEQD} \text{ QBD} + \text{CQDG} \text{ QBARD}$$

$$3.10 \quad \text{QBERR} = \text{QBREF} - \text{QBARF}$$

$$3.11 \quad \text{If DEF_AD} = \text{TRUE}, \text{ then QBERR} = \text{QBREF} - \text{QBAR_N}$$

$$3.12 \quad \text{EAS_CMD} = 17.1865 \text{ SQRT}(\text{QBREF})$$

4. The auto PTI acceptable discrete is set FALSE if the altitude acceleration exceeds the limit for auto PTI's.

$$4.1 \quad \text{GUID_ACCEP} = \text{ON}$$

$$4.2 \quad \text{If ABS}(\text{ACC_VERT}) \geq \text{VERTACLIMIT}, \text{ then GUID_ACCEP} = \text{OFF}$$

B. Interface Requirements. The input/output parameters for TGCOMP are shown in Table 4.6.2.6-1. The I-loads/constants are defined in Table 4.6.2.6-2.

C. Processing Requirements. TGCOMP is executed at the TAEM guidance rate after GTP during the entire TAEM major mode.

D. Initialization Requirements. QBARF and QBD are initialized in TGINIT before the first pass through TGCOMP.

Table 4.6.2.6-1. TGCOMP Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
RPRED	Predicted ground track range to the runway threshold	GTP	ft	F
XALI	Trajectory reference point	TGXHAC	ft	F
IGS	Glideslope index	TGINIT	ND	I
V	Ground relative velocity magnitude	NAV	ft/sec	F
H	Altitude of the wheels above the runway	NAV	ft	F
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
QBARF	Filtered dynamic pressure	TGINIT	psf	F
QBAR_N	NAV-derived dynamic pressure	NAVDAD SOP	psf	F
QBD	Filtered dynamic pressure rate	TGINIT	psf/sec	F
DEF_AD	Default air data flag	ADTA SOP	ND	D
DEF_ADO	Past value of DEF_AD	TGINIT	ND	D
RPRED2	Range from HAC to runway	GTP	ft	F
IPHASE	TAEM PHASE counter	TGINIT, TGTRAN	ND	I
PSHA	HAC turn angle	GTP	deg	F
RF	HAC radius at PSHA = 0°	TGINIT	ft	F
ACC_VERT	Vertical accel in topodetic coord	NAV	ft/sec ²	F
V_PAST	Past value of V	TGINIT	ft/sec	F
OUTPUTS				
HERROR	Altitude error	TGNZC, TGTRAN, TLM, HUD PROC, HORIZ SIT SPEC, E/L ADI PROC	ft	F
DHDRRF	Reference flight path angle	TGNZC, TLM	ND	F
QBARF	Filtered dynamic pressure	TGNZC	psf	F
QBD	Filtered dynamic pressure rate	TGNZC, TLM	psf/sec	F
QBERR	Dynamic pressure error	TGTRAN, TGSBC, TLM	psf	F
EAS_CMD	Equivalent airspeed command	TLM	kt	F
EOW	Energy over weight	TGTRAN, TGSBC, TGNZC, VERT SIT DIP	ft	F
IEL	Energy reference index	TGSBC	ND	I

Table 4.6.2.6-1. TGCOMP Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
EN	Reference energy over weight	TGTRAN, TGSBC, TGNZC, VERT SIT DIP	ft	F
GUID_ACCEP	Auto PTI acceptable discrete	PTI (AEROJET DAP)	ND	D
QBREF	Dynamic pressure reference	TLM, HUD PROC	psf	F
HREF	Reference altitude	TLM	ft	F
DRPRED	RPRED + XALI	TGTRAN	ft	F
RF	HAC radius at PSHA = 0°	GTP, ENT AREA, NAV, HORIZ SIT SPEC	ft	F
ES	Energy over weight reference for S-turn initiation	TGTRAN, VERT SIT DIP	ft	F
EMEP	Energy over weight reference for MEPALERT status	TGTRAN, VERT SIT DIP	ft	F
EMAX	Upper energy over weight reference for NZC limiting	TGNZC, VERT SIT DIP	ft	F
EMIN	Lower energy over weight reference for NZC limiting	TGNZC, VERT SIT DIP	ft	F

Table 4.6.2.6-2. TGCOMP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0287C V97U0288C	HALI(I)*	Altitude used to define XALI		ft	SX
V97U6116C	DTG	Time step between guidance calls	0.96	sec	X
V97U0355C	QBARDL	Limit on QBARD		psf/sec	SX
V97U0358C V97U0359C	QBC2(I)*	Slope of QBREF for DRPRED < PBRCQ(I)*		psf/ft	MX
V97U0373C V97U0374C	QBRLI(I)*	QBREF lower limit		psf	MX
V97U0377C V97U0378C	QBRUL(I)*	QBREF upper limit		psf	MX
V90A7622C	GO	Acceleration of gravity at sea level	32.174049	ft/sec ²	X
V97U0199C V97U0200C	EOW_SPT(I)*	Range for IEL selection		ft	MX
V97U0173C V97U0174C V97U0177C V97U0178C	EN_C1(I,J)**	Constant energy used to determine EN		ft	MX

Table 4.6.2.6-2. TGCOMP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0181C V97U0182C V97U0185C V97U0186C	EN_C2(I,J)**	Slope of EN with range		ND	MX
V97U0414C V97U0415C	TGGS(I)*	Tangent of A/L steep glide slope ref		ND	MX
V97U0103C V97U0104C	CUBIC_C3(I)*	Coefficient used to determine HREF and DHDRRF		ft ⁻¹	MX
V97U0105C V97U0106C	CUBIC_C4(I)*	Coefficient used to determine HREF and DHDRRF		ft ⁻¹	MX
V97U0327C V97U0328C	PBGC(I)*	Minimum value for d(HREF)/d(RPRED)		ND	MX
V97U0077C	CQG	Constant gain used to compute QBARD		sec ⁻¹	SX
V97U0073C	CDEQD	Constant gain used to compute QBD		ND	SX
V97U0076C	CQDG	Constant gain used to compute QBD		ND	SX
V97U0356C V97U0357C	QBC1(I)*	Slope of QBREF for DRPRED ≥ PBRCQ(I)*		psf/ft	MX
V97U0333C V97U0334C	PBRCQ(I)*	Range break point for QBREF		ft	MX
V97U0375C V97U0376C	QBRML(I)*	QBREF middle limit		psf	MX
V97U0331C V97U0332C	PBRC(I)*	Maximum range for cubic altitude reference		ft	MX
V97U0329C V97U0330C	PBHC(I)*	Altitude reference for DRPRED = PBRC(I)*		ft	MX
V97U0536C	V_DEF	NAVDAD/default dynamic pressure switch velocity		ft/sec	MX
V97U0383C	RAD_PER_DEG	Degree to radian conversion factor	0.017453293	rad/deg	X
V96U8673C	R2MAX	Maximum range for subsonic HAC interceptwith nominal dynamic pressure		ft	SX
V96U8643C	ESHFMX	Maximum shift of HAC targeted EN		ft	SX
V96U8648C	PSRF	Maximum PSHA for RF adjustment		deg	SX
V96U8639C	DHOH1	Slope for spiral altitude reference deviation		ND	SX
V96U8640C	DHOH2	Range bias for spiral altitude reference deviation		ft	SX
V96U8641C	DHOH3	Limit for spiral altitude reference deviation		ft	SX
V96U8661C	RFMN	Minimum final HAC turn radius		ft	SX
V96U8662C	RFMX	Maximum final HAC turn radius		ft	SX
V96U8663C	DRFK	RF adjustment gain		ND	SX

Table 4.6.2.6-2. TGCOMP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0219C V97U0223C	ES1(I)*	Constant energy over weight used to calculate ES		ft	MX
V97U0146C V97U0150C	EDRS(I)*	Slope of ES with range		ND	MX
V97U0161C V97U0162C V97U0164C V97U0165C	EMEP_C1 (I,J)**	Constant energy over weight used to calculate EMEP		ft	MX
V97U0167C V97U0168C V97U0170C V97U0171C	EMEP_C2 (I,J)**	Slope of EMEP with range		ND	MX
V97U0144C V97U0145C	EDELNZ(I)*	Delta energy used in computing EMAX and EMIN		ft	MX
V97U0115C V97U0116C	DEL_R_ EMAX(I)*	Delta range used in computing EMAX		ft	MX
V97U0142C	EDEL C1	Constant used in determination of EMAX		ND	MX
V97U0143C	EDEL C2	Constant used in determination of EMAX		ND	MX
V99U6337C	VERTACLIMT	Vert accel limit for auto PTI		ft/sec ²	MX
*I = 1, 2					
**I = 1, 2; J = 1, 2					

4.6.2.7 Phase Transition, MEP, and OHALRT Function (TGTRAN).

This module determines all TAEM phase transitions and performs any initialization required due to a phase transition. Also, this function checks for a minimum entry point (MEP) situation and sends out the MEPALERT flag to DI if required. An overhead HAC low energy situation is also checked and if true, the TAEM guidance downmoding flag, OHALRT, is sent to DI to flash Item 6 on the HSD. S–turn (IPHASE = 0) initiation and termination as well as the MEP and OHALRT checks are based on energy over weight errors. If $EOW > EN$, the vehicle is high in energy; and if $EOW < EN$, the vehicle is low in energy.

The TAEM program normally will be entered in the acquisition phase (IPHASE = 1). In the normal situation, the orbiter will remain in this phase until the heading alignment phase is initiated. However, if the energy state is too high, the S–turn phase will be initiated unless the predicted range is less than the minimum range allowed for an S–turn (RMINST) or the HAC turn angle, PSHA, is greater than a predetermined value, PSSTRN. The main objective of the S–turn is to rotate heading so that a longer ground path can be covered without getting into a geometry problem with respect to the HAC. This geometry problem exists only for HAC turn angles ≤ 135 degrees, but the capability for doing S–turns even with the overhead HAC is possible through proper selection of the value for PSSTRN. The direction in which the S–turn is made depends on which side of the runway centerline the HAC is located and on the orbiter heading. The logic for selection of the turn direction is

$$S = -YSGN$$

$$\text{If } S \psi_{RW} < 0 \text{ and } \psi_{HA} < 90, S = -S$$

where

$$S = -1 = \text{left bank}$$

$$S = +1 = \text{right bank}$$

Termination of the S–turn occurs when the energy error becomes less than ENBIAS, i.e., $EOW < EN + ENBIAS$.

During the acquisition phase, the MEPALERT flag will be issued whenever EOW becomes less than the MEP value for EOW (EMEP) and the NEP flag is “TRUE.” Transition to the heading alignment phase from the acquisition phase occurs whenever $RCIR < P2TRNC1 \cdot RTURN$ where RCIR is the orbiter’s radial distance from the HAC center and RTURN is the HAC radius.

Transition to the prefinal phase (IPHASE = 3) occurs whenever the predicted range is less than the prefinal initiation range value (RPRED3) or if altitude is less than a predetermined value (H_MIN_3).

After phase 3 is initiated, the TAEM–to–Approach/Land transition logic is executed to determine when the transition to A/L will take place.

Deviations from the normal functional operations of TGTRAN involve those processing requirements necessary to support a bailout abort. If a bailout abort is desired (via an ATO abort request subject to major mode and velocity constraints), a BAILOUT_ARM flag is set and latched. This flag will be used to prevent transition to A/L and will provide feedback to the crew for confirmation of the bailout request. FCS CSS/Auto command axis moding is then monitored to establish the state of the BAILOUT_BANK and BAILOUT_PITCH flags as used to configure the guidance for bailout roll and pitch command operations.

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A. Detailed Requirements. Upon entering TGTRAN, the bailout request flag is checked, and if TRUE, the BAILOUT_ARM flag is set to TRUE and latched as shown in Equation 0.1.

$$0.1 \quad \text{If (BAILOUT_FLAG = ON), then BAILOUT_ARM = ON}$$

The BAILOUT_BANK or BAILOUT_PITCH discrete is set to TRUE once the BAILOUT_ARM discrete is TRUE and whenever the appropriate FCS command channel axis is moded from CSS to auto as shown in Equations 0.2 and 0.3.

$$0.2 \quad \text{If (BAILOUT_ARM = ON and AUTORY_LAMP = ON and AUTORY_LAMP_PAST = OFF), then BAILOUT_BANK = ON}$$

$$0.3 \quad \text{If (BAILOUT_ARM = ON and AUTOP_LAMP = ON and AUTOP_LAMP_PAST = OFF), then BAILOUT_PITCH = ON}$$

Past values for the FCS command axis moding discrettes are saved as shown in Equations 0.4 and 0.5.

$$0.4 \quad \text{AUTORY_LAMP_PAST = AUTORY_LAMP}$$

$$0.5 \quad \text{AUTOP_LAMP_PAST = AUTOP_LAMP}$$

Whenever an FCS command axis is being operated in a CSS mode condition, the corresponding bailout bank or pitch discrete is set to FALSE as shown in Equations 0.6 and 0.7.

$$0.6 \quad \text{If (AUTORY_LAMP = OFF), then BAILOUT_BANK = OFF}$$

$$0.7 \quad \text{If (AUTOP_LAMP = OFF), then BAILOUT_PITCH = OFF}$$

If IPHASE = 3, a logical test is made for termination of TAEM guidance by the statement:

$$\text{If } \left((\text{ABS}(\text{HERROR}) < (\text{H_DEL_H1} - \text{DEL_H2})) \text{ and } (\text{ABS}(\text{Y}) < (\text{H_Y_RANGE1} - \text{Y_RANGE2})) \text{ and } (\text{ABS}(\text{GAMMA} - \text{GAMSGS}_{\text{IGS}}) < (\text{H_GAMMA_COEF1} - \text{GAMMA_COEF2})) \text{ and } (|\text{QBERR}| < \text{QB_ERROR2}) \text{ and } (\text{H_REF1} > \text{H}) \text{ or } (\text{H} < \text{H_REF2}) \right) \text{ and } (\text{BAIL_ARM} = \text{FALSE})$$

then the TAEM guidance termination flag is set to TRUE, i.e.

$$\text{TG_END} = \text{TRUE}$$

and then the TGTRAN function is exited. Otherwise (IPHASE \neq 3), a test for transition to the prefinal phase (IPHASE = 3) is made on the basis of whether the predicted range is less than the prefinal initiation range value (RPRED < RPRED3), or if altitude is less than the minimum prefinal initiation value (H < H_MIN_3). If this test is true, Equation Set 1 is executed:

$$1.1 \quad \text{IPHASE} = 3$$

$$1.2 \quad \text{PHIO} = \text{PHIC}$$

- 1.3 PHILIM = PHILM3
- 1.4 DNZUL = DNZUC2
- 1.5 DNZLL = DNZLC2

If the prefinal initiation test is false (i.e., $RPRED \geq RPRED3$ and $H \geq H_MIN_3$), the appropriate logic based on the current TAEM phase is executed as follows:

For IPHASE = 0 (S–turn):

If the current energy over weight is less than the biased reference energy over weight $EOW < EN + ENBIAS$, then Equation Set 2 is executed:

- 2.1 IPHASE = 1
- 2.2 PHILIM = PHILM1

For IPHASE = 1 (acquisition)

1. If the HAC turn angle is less than the S–turn initiate constraint and the range to XALI is greater than the S–turn initiate minimum constraint ($PSHA < PSSTRN$ and $DRPRED > RMINST_{IGS}$) the S–turn initiation logic is executed as follows:

The test to initiate an S–turn is made on the basis of passing the following criteria:

$$EOW \geq ES$$

If this test is passed (true), Equation Set 3.2 is executed:

- 3.2.1 IPHASE = 0
 - 3.2.2 PHILIM = PHILM0
 - 3.2.3 $S = -YSGN$
 - 3.2.4 $SPSI = S \text{ RES180(PSD)}$
 - 3.2.5 If $SPSI < 0$ and $PSHA < 90$, then $S = -S$
2. Next, the tests for determining an MEP or OHALRT situation are made.

$$3.3 \quad EMOH = EMOHC1_{IGS} + DRPRED \text{ EMOHC2}_{IGS}$$

Then the criterion for issuing an MEPALERT discrete is based on passing the following test:

$$EOW < EMEP \text{ and } NEP = ON$$

If this test is true, then the MEP alert discrete is set to true (MEPALERT = TRUE); otherwise, the MEP alert discrete is set to false (MEPALERT = FALSE).

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Next, the test for determining an OHALRT situation is made as follows:

If $EOW < EMOH$ and $PSHA > PSOHAL$ and $RPRED > RMOH$,

then $OHALRT = ON$;

else $OHALRT = OFF$

3. The test for transition to the heading alignment phase ($IPHASE = 2$) is now made. First, a test on $RCIR$ is made. If $RCIR < P2TRNC1$ $RTURN$ is satisfied, Equation Set 3.5 is executed.

3.5.1 $IPHASE = 2$

3.5.2 $PHILIM = PHILM2$

For $IPHASE = 2$ (heading alignment), no additional calculations are presently required.

B. Interface Requirements. The input/output parameters for $TGTRAN$ are listed in Table 4.6.2.7-1. The I-loads are listed in Table 4.6.2.7-2.

C. Processing Requirements. $TGTRAN$ is executed at the $TAEM$ guidance rate after $TGTRAN$.

D. Initialization Requirements. $IPHASE$ and TG_END are initialized in $TGINIT$. The $BAILOUT_ARM$, $BAILOUT_PITCH$, and $BAILOUT_BANK$ flags are initialized to OFF prior to first pass through $TAEM$ guidance.

E. Supplemental Information. The following function is called by $TGTRAN$: $RES180$.

Table 4.6.2.7-1. TGTRAN Input/Output Parameters

Name	Description	Source/Destination	Units	Type
INPUT				
RPRED	Predicted ground track range to the runway threshold	GTP	ft	F
RPRED3	Prefinal initiation range value	TGXHAC	ft	F
PHIC	Unlimited roll command	TGPHIC	deg	F
IPHASE*	TAEM phase counter	TGINIT	ND	I
NEP	Nominal Entry Point Flag	HORIZ SIT DISP	ND	D
QBERR	Current dynamic pressure error	TGCOMP	psf	F
YSGN	Sign of crossrange position wrt runway of selected HAC	NAV	ND	F
PSD	Heading with respect to runway centerline	NAV	deg	F
RCIR	Radial distance from center of closest HAC	GTP	ft	F
HERROR	Altitude error	TGCOMP	ft	F
Y	Cross range position with respect to runway	NAV	ft	F
GAMMA	Ground relative flight path angle	NAV	deg	F
H	Altitude of wheels above runway	NAV	ft	F
EN	Reference energy over weight	TGCOMP	ft	F
IGS	Glide slope index	TGINIT	ND	I
EOW	Energy over weight	TGCOMP	ft	F
DRPRED	RPRED + XALI	TGCOMP	ft	F
PSHA	HAC turn angle	GTP	deg	F
RTURN	Spiral turn radius	GTP	ft	F
ES	Energy over weight reference for S–turn initiation	TGCOMP	ft	F
EMEP	Energy over weight reference for MEPALERT status	TGCOMP	ft	F
BAILOUT_ FLAG	Bailout request flag	MSC	ND	D
AUTOP_LAMP	Auto lamp status, pitch axis	AEROJET DAP	ND	D
AUTORY_ LAMP	Auto lamp status, roll/yaw axis	AEROJET DAP	ND	D
AUTOP_ LAMP_PAST	Past value of auto lamp status, pitch axis	TGINIT	ND	D
AUTORY_ LAMP_PAST	Past value of auto lamp status, roll/yaw axis	TGINIT	ND	D
*Note: IPHASE is both an input and an output as indicated.				

Table 4.6.2.7-1. TGTRAN Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
OUTPUT				
MEPALERT	MEP alert status	GAX	ND	D
IPHASE*	TAEM phase counter	TGNZC, TLM, TGSBC, TGPHIC, GTP, ENT AREA NAV, NAV, HUD PROC, VERT SIT DIP, HORIZ SIT SPEC, E/L ADI PROC, MEDS FC GNC XFER	ND	I
BAILOUT_ARM	Bailout arm flag	TGSBC, TGPHIC, VERT SIT 1&2	ND	D
BAILOUT_BANK	Bailout bank flag	TGPHIC, VERT SIT 1&2	ND	D
BAILOUT_PITCH	Bailout pitch flag	TGNZC, VERT SIT 1&2	ND	D
DNZUL	Upper limit on normal acceleration command	TGNZC	g	F
DNZLL	Lower limit on normal acceleration command	TGNZC	g	F
PHIO	Previous unlimited roll command	TGPHIC	deg	F
PHILIM	TAEM phase dependent roll command limit	TGPHIC	deg	F
S	Sign of the S–turn roll command	TGPHIC, TLM	ND	F
TG_END	TAEM guidance termination flag	MSC, AEROJET DAP, E/L ADI PROC, VERT SIT DIP, HORIZ SIT SPEC, SPI PROC, VERT SIT 2, TLM, HUD PROC, NAV, MEDS FC GNC XFER, GN&C/ SM-PL IF	ND	D
EMOH	Energy over weight reference for OHALRT	VERT SIT DIP	ft	F
OHALRT	TAEM guidance downmode flag	GAX, HORIZ SIT DISP	ND	D
*Note: IPHASE is both an input and an output as indicated.				

Table 4.6.2.7-2. TGTRAN I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V96U8666C	EMOHC1(I)*	Constant energy over weight used to calculate EMOH		ft	MX
V96U8667C					
V96U8668C	EMOHC2(I)*	Slope of EMOH with range		ND	MX
V96U8669C					
V96U8670C	ENBIAS	Energy over weight bias for S–turn termination		ft	SX
V96U8651C	PSSTRN	Maximum allowable value for PSHA for S–turn initiation		deg	SX
V97U0387C	RMINST(I)*	Minimum range to initiate S–turn phase		ft	MX
V97U0388C					
V97U0343C	PHILM0	Roll command limit – S–turn		deg	SX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX
V97U0345C	PHILM2	Roll command limit – heading alignment		deg	SX
V97U0346C	PHILM3	Roll command limit – prefinal		deg	SX
V97U0351C	P2TRNC1	Constant used in Phase 2 transition logic		ND	SX
V97U0125C	DNZLC2	Phase 3 NZC lower limit		g	SX
V97U0127C	DNZUC2	Phase 3 NZC upper limit		g	SX
V97U0236C	GAMSGS(I)*	Autoland steep glide slope flight path angle		deg	MX
V97U0237C					
V97U0354C	QB_ERROR2	Dynamic pressure error bound		psf	SX
V97U0279C	H_REF1	Altitude reference		ft	SX
V97U0280C	H_REF2	Altitude reference		ft	SX
V97U0113C	DEL_H1	Altitude error coefficient		ND	SX
V97U0114C	DEL_H2	Altitude error coefficient		ft	SX
V97U0462C	Y_RANGE1	Cross range coefficient		ND	SX
V97U0463C	Y_RANGE2	Cross range coefficient		ft	SX
V97U0230C	GAMMA_COEF1	Flight path error coefficient		deg/ft	SX
V97U0231C	GAMMA_COEF2	Flight path error coefficient		deg	SX
V96U8305C	H_MIN_3	Minimum altitude for prefinal initiation		ft	SX
V96U8649C	PSOHAL	Minimum value for PSHA to issue OHALRT		deg	SX
V96U8672C	RMOH	Minimum range value to issue OHALRT		ft	SX

*I = 1, 2

4.6.2.8 Normal Acceleration Command Function (TGNZC).

The function TGNZC computes the incremental normal acceleration command, NZC, to the FCS for all TAEM phases. The command is generated from a computed altitude rate error term (HDERR) and from the altitude error input from TGCOMP. The upper and lower limits on the command are based on energy over weight, dynamic pressure, and TAEM phase considerations. A filter on the limited command (DNZCL) is implemented to smooth the command for all TAEM phases except prefinal (IPHASE = 3).

A deviation from normal TGNZC operations is the processing necessary to support bailout command requirements. Whenever the bailout mode is engaged in the pitch axis as reflected by the BAILOUT_PITCH flag being set to TRUE, the current dynamic pressure will be “snapped” and become the target dynamic pressure which will then be used to derive the normal acceleration command but within angle-of-attack constraints. Also upon bailout engagement, the Nz command output to the FCS, NZC, will be reset to the target dynamic pressure and angle-of-attack limited NZC command, DNZCL, to minimize FCS transients. If the bailout mode is subsequently disengaged (i.e., BAILOUT_PITCH set to FALSE), the Nz command will reflect resumption of normal command processing requirements.

A. Detailed Requirements. Upon entering TGNZC, the unlimited normal acceleration command (DNZC) and the upper and lower dynamic pressure limits (QBMXNZ, QBMNNZ) are computed using Equation Set 1.

- 1.1 $GDH = \text{MIDVAL}(GDHC - GDHS \ H, GDHLL, GDHUL)$
- 1.2 $HDREF = VH \ DHDRRF$
- 1.3 $HDERR = HDREF - HDOT$
- 1.4 $DNZC = DNZCG \ GDH (HDERR + HDREQG \ GDH \ HERROR)$

Generate minimum dynamic pressure profile

- 1.5 If $MACH < QMACH2$, then $MXQBWT = \text{MIDVAL}(QBWT1, QBWT2, QBWT1 + QBMSL1 (MACH - QMACH1))$, else $MXQBWT = \text{MIDVAL}(QBWT2, QBWT3, QBWT2 + QBMSL2 (MACH - QMACH2))$
- 1.6 $QBLL = MXQBWT \ MASS$
- 1.7 $QBMNNZ = QBLL/\text{MAX}(\text{SCALAR}(\text{COSPHI}, \text{CPMIN}))$

Generate maximum dynamic pressure profile.

- 1.8 IF $MACH > QBM1$, then $QBMXNZ = \text{MIDVAL}(QBMX2 + QBMXS2 (MACH - QBM2), QBMX2, QBMX3)$, else $QBMXNZ = \text{MIDVAL}(QBMX2 + QBMXS1 (MACH - QBM1), QBMX1, QBMX2)$

In the transonic energy region for an overhead HAC approach, the maximum dynamic pressure profile is lowered to target for subsonic conditions at HAC initiation.

- 1.9 If $EQLOWL < EOW$ and $EOW < EQLOWU$ and $PSHA > PSOHQB$, then $QBMXNZ = \text{MIDVAL}(QBMNNZ, QBMXNZ, QBREF2_{IGS} - PQBWRR (RPRED2 - R2MAX + (EOW - EN)/PEWRR))$

Next, the upper and lower dynamic pressure limits on the normal acceleration command are computed using Equation Set 2.

- 2.1 If (BAILOUT_PITCH = ON), then execute Equations 2.1.1 through 2.1.3.
 - 2.1.1 If (ISNAPP = OFF), then execute Equations 2.1.1.1 through 2.1.1.3.
 - 2.1.1.1 $QBARS = QBARF$
 - 2.1.1.1.1 $ISNAPP = ON$
 - 2.1.1.3 $ICGUID = ON$
 - 2.1.2 $QBMNNZ = QBARS$
 - 2.1.3 $QBMXNZ = QBARS$

If the bailout engagement test fails (i.e., BAILOUT_PITCH = OFF), then the ISNAPP discrete is set to OFF.

- 2.2 $QBNZUL = -(QBG1 (QBMNNZ - QBARF) - QBD) QBG2$
- 2.3 $QBNZLL = -(QBG1 (QBMXNZ - QBARF) - QBD) QBG2$

If (IPHASE = 3 and BAILOUT_PITCH = OFF), then $NZC = MIDVAL(DNZC, QBNZLL, QBNZUL)$. Otherwise (IPHASE \neq 3 or BAILOUT_PITCH = ON), DNZC limits based on energy over weight are calculated, and the unlimited command is then limited by both the energy over weight and dynamic pressure limits and is then filtered as shown in Equation Set 3.

- 3.1 $EOWNZUL = (GDH GEUL (EMAX - EOW) + HDERR) GDH GEHDUL$
- 3.2 $EOWNZLL = (GDH GELL (EMIN - EOW) + HDERR) GDH GEHDLL$
- 3.3 $DNZCL = MIDVAL(DNZC, EOWNZLL, EOWNZUL)$
- 3.4 $DNZCL = MIDVAL(DNZCL, QBNZLL, QBNZUL)$
- 3.5 If (BAILOUT_PITCH = ON), then execute Equations 3.5.1 through 3.5.5
 - 3.5.1 $ALPH = MIDVAL(ALPHA, 0.0, ALPQL)$
 - 3.5.2 $ALPNZUL = (ALPE1 (ALPCMDL - ALPH) - Q) ALPE2$
 - 3.5.3 $DNZCL = MIDVAL(DNZCL, -5.0, ALPNZUL)$
 - 3.5.4 If (ICGUID = ON), then $NZC = DNZCL$
 - 3.5.5 $ICGUID = OFF$
- 3.6 $DNZCD = MIDVAL((DNZCL - NZC) CQG, -DNZCDL, DNZCDL)$
- 3.7 $NZC = NZC + DNZCD DTG$

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Finally, for all phases, NZC is limited between the upper and lower phase dependent limits (DNZLL, DNZUL) by $NZC = \text{MIDVAL}(NZC, DNZLL, DNZUL)$.

B. Interface Requirements. The input/output parameters for TGNZC are listed in Table 4.6.2.8–1. The I–loads/constants are listed in Table 4.6.2.8–2.

C. Processing Requirements. TGNZC is executed at the TAEM guidance rate.

D. Initialization Requirements. NZC must be initialized to zero before the first entry into TGNZC. ICGUID and ISNAPP flags must be initialized to OFF prior to the first pass through TGNZC.

Table 4.6.2.8-1. TGNZC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
H	Altitude of rear wheels above runway	NAV	ft	F
VH	Horizontal component of ground relative velocity	NAV	ft/sec	F
HDOT	Estimated altitude rate	NAV	ft/sec	F
COSPHI	Euler angle roll cosine	A/E ATT PROC	ND	F
MACH	GN&C Mach number	ADTA SOP	ND	F
IPHASE	TAEM phase counter	TGINIT, TGTRAN	ND	I
DHDRRF	Tangent of the reference flight path angle	TGCOMP	ND	F
HERROR	Altitude error	TGCOMP	ft	F
QBARF	Filtered dynamic pressure	TGCOMP	psf	F
QBD	Filtered dynamic pressure rate	TGCOMP	psf/sec	F
DNZUL	Upper limit on normal acceleration command	TGINIT, TGTRAN	g	F
DNZLL	Lower limit on normal acceleration command	TGINIT, TGTRAN	g	F
EN	Reference energy over weight	TGCOMP	ft	F
EOW	Energy over weight	TGCOMP	ft	F
IGS	Glide slope index	TGINIT	ND	I
MASS	Orbiter mass	DEORBIT GUID	slugs	F
PSHA	HAC turn angle	GTP	deg	F
RPRED2	Range from HAC to runway	GTP	ft	F
EMAX	Upper energy over weight reference for NZC limiting	TGCOMP	ft	F
EMIN	Lower energy over weight reference for NZC limiting	TGCOMP	ft	F
BAILOUT_PITCH	Bailout pitch flag	TGTRAN	ND	D
ALPHA	Angle of attack	ADTA SOP	deg	F
Q	Pitch rate feedback	SF	deg/sec	F
OUTPUTS				
NZC	Normal acceleration command	AEROJET DAP, TLM, TGPHIC	g	F
EOWNZLL	Energy lower limit – NZC	TLM	g	F
EOWNZUL	Energy upper limit – NZC	TLM	g	F
QBMNNZ	Lower limit on dynamic pressure	TLM	psf	F
QBMXNZ	Upper limit on dynamic pressure	TLM	psf	F
QBNZLL	Dynamic pressure lower limit – NZC	TLM	g	F
QBNZUL	Dynamic pressure upper limit – NZC	TLM	g	F

Table 4.6.2.8-2. TGNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U6116C	DTG	Time step between TAEM guidance calls	0.96	sec	X
V97U0238C	GDHC	Constant for computing GDH		ND	SX
V97U0240C	GDHS	Slope for computing GDH		ft ⁻¹	SX
V97U0239C	GHDLL	GDH lower limit		ND	SX
V97U0241C	GDHUL	GDH upper limit		ND	SX
V97U0123C	DNZCG	Gain used to compute DNZC		g-sec/ft	SX
V97U0075C	CPMIN	Minimum value of cosine of phi used in computation of QBMNNZ		ND	SX
V97U0367C	QBMX1	Constant for computing QBMXNZ		psf	SX
V97U0371C	QBM1	Mach break point in computing QBMXNZ		ND	SX
V97U0368C	QBMX2	Constant for computing QBMXNZ		psf	SX
V96U8676C	QBMXS1	Slope of QBMXNZ for MACH ≤ QBM1		psf	SX
V97U0366C	QBMXS2	Slope of QBMXNZ for MACH > QBM1		psf	SX
V97U0372C	QBM2	Mach break point in computing QBNXNZ		ND	SX
V97U0369C	QBMX3	Constant for computing QBMXNZ		psf	SX
V97U0360C	QBG1	Gain used to compute QBNZUL and QBNZLL		sec ⁻¹	SX
V97U0361C	QBG2	Gain used to compute QBNZUL and QBNZLL		sec-g/psf	SX
V97U0290C	HDREQG	Gain on HERROR component of DNZC		sec ⁻¹	SX
V97U0245C	GEUL	Constant gain for computing EOWNZUL		sec ⁻¹	SX
V97U0244C	GELL	Constant gain for computing EOWNZLL		sec ⁻¹	SX
V97U0243C	GEHDUL	Constant gain for computing EOWNZUL		g-sec/ft	SX
V97U0242C	GEHDLL	Constant gain for computing EOWNZLL		g-sec/ft	SX
V97U0077C	CQG	Constant gain used to compute DNZCD		sec ⁻¹	SX
V96U8656C	QBWT1	Constant used to compute MXQBWT		psf/slug	SX
V96U8657C	QBWT2	Constant used to compute MXQBWT		psf/slug	SX
V96U8658C	QBWT3	Constant used to compute MXQBWT		psf/slug	SX
V96U8652C	QBREF2(I)*	Targeted dynamic pressure at R2MAX		psf	MX
V96U8653C					
V96U8673C	R2MAX	Nominal range for subsonic roll maneuvers (MACH = PHIM)		ft	SX
V96U8645C	PEWRR	Partial of EN wrt range-to-go at R2MAX		ND	SX
V96U8646C	PQBWRR	Partial of dynamic pressure wrt range-to-go at EOW = EN and MACH = PHIM		psf/ft	SX
V97U0122C	DNZCDL	Limit on NZC rate of change		g/sec	SX
V96U8642C	EQLOWU	Upper limit on EOW for resetting QBMXNZ		ft	SX
V96U8671C	EQLOWL	Lower limit on EOW for resetting QBMXNZ		ft	SX
V96U8650C	PSOHQB	Minimum value for PSHA for resetting QBMXNZ		deg	SX
V99U9963C	ALPQL	Maximum angle-of-attack limit		deg	SX

Table 4.6.2.8-2. TGNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V99U9961C	ALPE1	Gain used to compute ALPNZUL		1/sec	SX
V99U9962C	ALPE2	Gain used to compute ALPNZUL		sec-g/deg	SX
V99U9964C	ALPCMDL	Maximum commanded angle-of-attack limit		deg	SX
V96U8654C	QBMSL1	Slope for MXQBWT when Mach < QMACH2		lbs/(slug ft ²)	SX
V96U8655C	QBMSL2	Slope for MXQBWT when Mach ≥ QMACH2		lbs/(slug ft ²)	SX
V96U8659C	QMACH1	Mach break point for computing MXQBWT		ND	SX
V96U8660C	QMACH2	Mach break point for computing MXQBWT		ND	SX
*I = 1, 2					

4.6.2.9 Speed Brake Command Function (TGSBC).

This module performs the calculations required to generate the speed brake command to the FCS for all TAEM phases. For $MACH > DSBCM$, $DSBC_AT = DSBSUP$; otherwise, the following is applicable: During an S-turn phase ($IPHASE = 0$), the speed brake command is simply $DSBLIM$. For all other phases, the unlimited command is based on a nominal speed brake command ($DSBNOM$), plus proportional terms based on a combination of energy, energy rate, and dynamic pressure errors. A blending function is provided to allow for an altitude dependent, linear transition from effectively only an energy and energy rate closed-loop speedbrake command to solely a dynamic pressure derived command to enable equivalence with A/L speedbrake command operations. Additionally, the derived energy rate error, $EDTERI$, is filtered to remove the 0.25 Hz noise introduced by the navigation in its calculation of drag deceleration, ACC_DRAG . Finally, for all phases, the FCS speed brake command, $DSBC_AT$, is calculated based on the unlimited command and the calculated limits. The calculated speed brake limits are Mach dependent schedules.

A deviation from the normal function of TGSBC is the request for a BAILOUT ABORT. A BAILOUT ABORT being declared will command the speed brake to close.

A. Detailed Requirements. If $MACH$ is greater than $DSBCM$, the speed brake command issued to the FCS, $DSBC_AT$, is set to a constant value of $DSBSUP$, and TGSBC is exited. Otherwise, $DSBC_AT$ is calculated from the following:

First, the command limits are calculated using Equation Set 1.

$$1.1 \quad DSBCLL = MIDVAL(DSBSUP + DSBLLS (MACH - DSBCM), 0, DSBSUP)$$

$$1.2 \quad DSBCUL = MIDVAL(DSBSUP + DSBULS (MACH - DSBCM), DSBSUP, DSBLIM)$$

Next, the unlimited speed brake command, $DSBC$, is calculated using Equation Set 2. If $IPHASE = 0$, Equation 2.1 is used; otherwise ($IPHASE \neq 0$) Equations 2.2 through 2.7 are used.

$$2.1 \quad DSBC = DSBLIM$$

$$2.2 \quad DSBE = GSBE QBERR$$

$$2.3 \quad BLEND = MIDVAL (HGAINSB (H - HBLEND), 0., 1.)$$

$$2.4 \quad EDTERI = V (EN_C2_{IGS, IEL} - ACC_DRAG / GO)$$

$$2.5 \quad \text{If first pass through Equations 2.2 through 2.7 then } EDTERO = EDTERI$$

$$2.6 \quad EDTERO = (1. - EDSMGAN) EDTERO + EDSMGAN EDTERI$$

$$2.7 \quad DSBC = DSBNOM + BLEND (EOWSBG (EOW - EN) + EDOTSBG EDTERO) - (1. - BLEND) DSBE$$

Finally, the speed brake command issued to the FCS, $DSBC_AT$, is calculated using Equation Set 3.

$$3.1 \quad \text{If } (BAILOUT_ARM = ON), \text{ then } DSBC = 0.0$$

$$3.2 \quad DSBC_AT = MIDVAL(DSBC, DSBCLL, DSBCUL)$$

- B. Interfacing Requirements. The input/output parameters for TGSBC are listed in Table 4.6.2.9-1. The I-loads/constants are listed in Table 4.6.2.9-2.
- C. Processing Requirements. TGSBC is executed at the TAEM guidance rate.
- D. Initialization Requirements. None
- E. Supplemental Information. None

Table 4.6.2.9-1. TGSBC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
BAILOUT_ARM	Bailout arm flag	TGTRAN	ND	D
MACH	GN&C Mach number	ADTA SOP	ND	F
QBERR	Dynamic pressure error	TGCOMP	psf	F
IPHASE	TAEM phase counter	TGINIT, TGTRAN	ND	I
EOW	Energy over weight	TGCOMP	ft	F
EN	Nominal energy over weight reference	TGCOMP	ft	F
ACC_DRAG	Drag deceleration	NAV	ft/sec ²	F
H	Altitude of wheels above runway	NAV	ft	F
V	Ground relative velocity magnitude	NAV	ft/sec	F
IEL	Energy reference index	TGCOMP	ND	I
IGS	Glide slope index	TGINIT	ND	I
OUTPUTS				
DSBC_AT	Commanded speed brake position	AEROJET DAP, SPI PROC, VERT SIT DIP, TLM	deg	F

Table 4.6.2.9-2. TGSBC I-Loads / Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0257C	GSBE	Speed brake proportional gain on QBERR		deg/psf	SX
V97U0134C	DSBNOM	Nominal speed brake command		deg	SX
V97U0133C	DSBLIM	Maximum value of speed brake command		deg	SX
V97U0131C	DSBCM	Mach at which speed brake modulation begins		ND	SX
V97U0135C	DSBSUP	Supersonic fixed speed brake deflection		deg	SX
V96U8664C	DSBLLS	Constant used to compute DSBCLL		deg	SX
V96U8665C	DSBULS	Constant used to compute DSBCUL		deg	SX
V97U0187C	HBLEND	Altitude for 100% dynamic pressure speedbrake control		ft	SX
V97U0188C	HGAINSB	Blender gain on altitude		ft ⁻¹	SX
V97U0190C	EDSMGAN	Energy rate error filter gain		ND	SX
V97U0192C	EOWSBG	Speedbrake gain on energy error		deg/ft	SX
V97U0194C	EDOTSBG	Speedbrake gain on energy rate error		deg-sec/ft	SX
V97U0181C	EN_C2(I, J)*	Slope of EN with range		ND	MX
V97U0182C					
V97U0185C					
V97U0186C					
V90A7622C	GO	Acceleration of gravity at sea level	32.174049	ft/sec ²	X
*I = 1,2; J = 1, 2					

4.6.2.10 Roll Command Function (TGPHIC).

The function TGPHIC computes the roll command, PHIC_AT, for the lateral axis command to the FCS for all TAEM phases. If the guidance is in the S–turn phase (IPHASE = 0), a constant roll command equal to S PHILIMIT is issued to the FCS where S is the sign of the roll command calculated in TGTRAN, and PHILIMIT is the maximum roll command allowed. During the acquisition phase (IPHASE = 1), a roll command is given which is proportional to the orbiter’s heading deviation from tangency to the nearest HAC. In the heading alignment phase (IPHASE = 2), the roll command is generated to assure that the orbiter performs a turn which follows the heading alignment cone. In the prefinal phase (IPHASE = 3), the roll command is generated from a linear combination of the orbiter’s lateral deviation and deviation rate from the runway centerline. The roll command limit, PHILIMIT, is a Mach dependent schedule with supersonic, phase dependent, and normal load limit constraints.

Deviations from the normal functional operations of TGPHIC involve those processing requirements necessary to support bailout commands. If the bailout mode has been requested but not engaged in the roll axis (i.e., BAILOUT_ARM = TRUE and AUTORY_LAMP = FALSE), the roll command is simply set to the current roll attitude. Whenever the bailout mode is engaged in the roll axis (e.g., BAILOUT_BANK = TRUE), the roll command will become fixed and will reflect the value of roll existent at the time of engagement.

A. Detailed Requirements. Upon entering TGPHIC, the roll command limit is calculated using PHILIMIT = MIDVAL(PHILMSUP + PHILS (MACH – PHIM), PHILMSUP, PHILIM); but if the air data system is in a default condition, the supersonic constraint is removed, i.e., if DEF_AD = ON, then PHILIMIT = PHILIM. Next, the unlimited roll command, PHIC, is generated on the basis of the current TAEM phase as follows:

1. IPHASE = 0 (S–turn):
 - 1.1 PHIC = S PHILIMIT
2. IPHASE = 1 (acquisition)
 - 2.1 PHIC = GPHI DPSAC
3. IPHASE = 2 (heading alignment):
 - 3.1 RERRC = RCIR – RTURN
 - 3.2 If RERRC > RERRLM, then execute Equation Set 3.3; otherwise, execute Equation Set 3.4.
 - 3.3.1 PHIC = GPHI DPSAC
 - 3.3.2 If PHILIMIT > PHILM1, then PHILIMIT = PHILM1
 - 3.4.1 $RDOT = -(XCIR \cdot XDOT + YCIR \cdot YDOT)/RCIR$
 - 3.4.2 $PHIP2C = (VH \cdot VH - RDOT \cdot RDOT) \cdot DEG_PER_RAD / (GO \cdot RTURN)$
PHIP2C = PHIP2C (PHI2C1 – PHI2C2 PHIP2C)

- 3.4.3 $RDOTRF = -VH (R1 + 2 R2 PSHA) DEG_PER_RAD/RTURN$
- 3.4.4 $PHIC = YSGN MAX(SCALAR(0, PHIP2C + GR RERRC + GRDOT (RDOT - RDOTRF)))$
- 4. IPHASE = 3 (prefinal):
 - 4.1 $YERRC = MIDVAL(-GY Y, -YERRLM, YERRLM)$
 - 4.2 $PHIC = YERRC - GYDOT YDOT$
 - 4.3 $PHILIMIT = MIDVAL(PHILM3, PHILM4, PHILR1 ABS(PHIC) + PHILR2)$
 - 4.4 If $ISR > 0$,
then
 - 4.4.1 $DPHI = (PHIC - PHIO)/ISR$
 - 4.4.2 $ISR = ISR - 1$
 - 4.4.3 $PHIC = PHIO + DPHI$
 - 4.4.4 $PHIO = PHIC$

After the required phase dependent roll command calculations are made, the normal load roll angle limit, PHINZ, is computed as shown in Equation 5.1. The Mach and phase dependent roll command limit, PHILIMIT, is then reset to PHINZ if it exceeds the normal load roll angle limit as shown in Equation 5.2

- 5.1 $PHINZ = ARCCOS (COSTH / (GMAX - NZC)) DEG_PER_RAD$
- 5.2 If $PHILIMIT > PHINZ$, then $PHILIMIT = PHINZ$

Finally, the roll command to the FCS, PHIC_AT, is calculated using Equation Set 6 which includes those specific provisions for bailout roll command processing as previously described.

- 6.1 $PHIC_AT = MIDVAL(PHIC, -PHILIMIT, PHILIMIT)$
- 6.2 If $(BAILOUT_ARM = ON$ and $AUTORY_LAMP = OFF)$, then $PHIC_AT = PHI$
- 6.3 If $(BAILOUT_BANK = ON)$, then execute Equations 6.3.1 and 6.3.2
 - 6.3.1 If $(ISNAPB = OFF)$, then
 - 6.3.1.1 $PHIC_ATS = PHI$
 - 6.3.1.2 $ISNAPB = ON$
 - 6.3.2 $PHIC_AT = PHIC_ATS$

If the bailout engagement test fails (i.e., BAILOUT_BANK = OFF), then the ISNAPB discrete is set to OFF.

B. Interface Requirements. The input/output parameters for TGPHIC are listed in Table 4.6.2.10-1. The I-loads/constants are listed in Table 4.6.2.10-2.

C. Processing Requirements. TGPHIC is executed at the TAEM guidance rate.

D. Initialization Requirements. PHILIM and GMAX are initialized in TGINIT, and PHIO is initialized in TGTRAN. The ISNAPB flag must be initialized to OFF prior to the first pass through TGPHIC.

Table 4.6.2.10-1. TGPHIC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
DEF_AD	Default air data flag	ADTA SOP	ND	F
MACH	GN&C Mach number	ADTA SOP	ND	F
IPHASE	TAEM phase counter	TGINIT, TGTRAN	ND	I
BAILOUT_ BANK	Bailout bank flag	TGTRAN	ND	D
XDOT	Downrange velocity with respect to the runway	NAV	ft/sec	F
BAILOUT_ ARM	Bailout arm flag	TGTRAN	ND	D
YDOT	Cross range velocity with respect to the runway	NAV	ft/sec	F
Y	Cross range position with respect to the runway	NAV	ft	F
AUTORY_ LAMP	AUTO lamp status for roll/yaw axis	AEROJET DAP	ND	D
VH	Horizontal ground speed	NAV	ft/sec	F
PHILIM	TAEM phase dependent roll command limit	TGINIT, TGTRAN	deg	F
PHI	Body roll attitude Euler angle	A/E ATT PROC	deg	F
RTURN	Spiral turn radius	GTP	ft	F
S	Sign of the S–turn roll command	TGTRAN	ND	F
PSHA	HAC turn angle	GTP	deg	F
YSGN	Sign of crossrange position wrt runway of selected HAC	NAV	ND	F
DPSAC	Heading error wrt HAC tangency	GTP	deg	F
XCIR	X distance from the nearest HAC center	GTP	ft	F
YCIR	Y distance from the nearest HAC center	GTP	ft	F
RCIR	Radial distance from the nearest HAC center	GTP	ft	F
ISR	Prefinal roll command fader counter	TGINIT	ND	I
PHIO	Previous unlimited roll command	TGTRAN	deg	F
GMAX	Maximum normal load limit	TGINIT	g	F
COSTH	Euler angle pitch cosine	A/E ATT PROC	ND	F
NZC	Normal acceleration command	TGNZC	g	F
OUTPUTS				
PHIC_AT	Commanded roll angle	AEROJET DAP, E/L ADI PROC, A/L GUID, TLM	deg	F
PHIC	Unlimited roll command	TGTRAN, TLM	deg	F
RDOT	Radial rate from HAC center	TLM	ft/sec	F

Table 4.6.2.10-1. TGPHIC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
RERRC	HAC radial error	TLM, HORIZ SIT SPEC, E/L ADI PROC	ft	F
YERRC	Roll command component due to lateral error for prefinal	TLM	deg	F

Table 4.6.2.10-2. TGPHIC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0246C	GPHI	Acquisition roll command gain on DPSAC		ND	SX
V97U0384C	RERRLM	Limit on RERRC		ft	SX
V97U0464C	YERRLM	Limit on YERRC		deg	SX
V97U0263C	GY	Prefinal roll command gain on Y		deg/ft	SX
V97U0264C	GYDOT	Prefinal roll command gain on YDOT		deg-sec/ft	SX
V97U0347C	PHIM	Mach at which supersonic roll command limit is removed		ND	SX
V97U0342C	PHILMSUP	Supersonic roll command limit		deg	SX
V97U0247C	GR	Gain on radial error in computing HA roll angle command		deg/ft	SX
V97U0253C	GRDOT	Gain on radial error rate in computing HA angle command		deg-sec/ft	SX
V96U8644C	PHILS	Constant used to calculate PHILIMIT		deg	SX
V97U0112C	DEG_PER_RAD	Radian-to-degree conversion factor	57.2957795131	deg/rad	X
V90A7622C	GO	Earth gravitational constant	32.174049	ft/sec ²	X
V96U8263C	R1	Coefficient of spiral		ft/deg	SX
V96U8264C	R2	Coefficient of spiral		ft/deg ²	SX
V96U8674C	PHILM4	Alternate Phase 3 roll command limit		deg	SX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX
V97U0346C	PHILM3	Roll command limit – prefinal		deg	SX
V99U7406C	PHILR1	Prefinal roll command limit slope		ND	SX
V99U7407C	PHILR2	Prefinal roll command limit constant		deg	SX
V96U7838C	PHI2C1	Coef ₁ of arctan curve fit		ND	SX
V96U7839C	PHI2C2	Coef ₂ of arctan curve fit		deg ⁻¹	SX

4.6.2.11 Resolve to 180 Degrees (RES180).

The function of RES180 is to resolve the input angle to lie within the range ± 180 degrees.

A. Detailed Requirements. Calling RES180 with the statement

$$ANG = RES180(ANG)$$

causes the function RES180 to execute the logic shown in Figure 4.6.2.11-1.

B. Interface Requirements. The input/output parameters for RES180 are listed in Table 4.6.2.11-1. There are no I-loads/constants for RES180.

C. Processing Requirements. This module is processed when called.

D. Initialization Requirements. None.

Table 4.6.2.11-1. RES180 Input/Output Parameters					
Name	Description	Source/Destination	Type	Units	Sample Rate (Hz)
INPUTS					
ANG	Angle to be resolved	Argument list	F	deg	TAEM guidance rate
OUTPUTS					
ANG	Resolved angle	Function	F	deg	

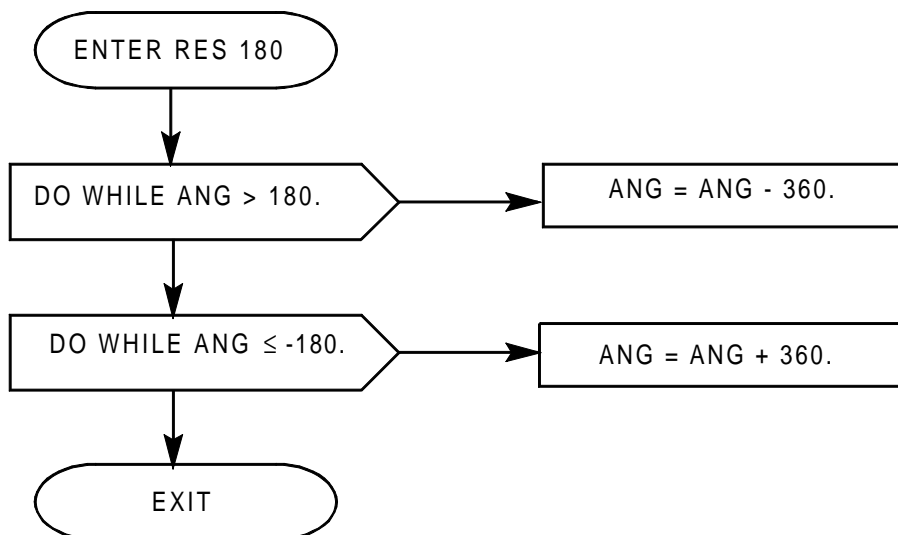


FIGURE 4.6.2.11-1. Resolve to 180 Degrees (RES 180)

4.6.3 Parameter Tables For TAEM Guidance (G4.9)

The IDD inputs and outputs are listed in Tables 4.6.3-1 and 4.6.3-2 respectively. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.6.3-3. K-loads are listed in Table 4.6.3-4. Constants are listed in Table 4.6.3-5.

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TABLE 4.6.3-1. INPUT FUNCTIONAL PARAMETERS FOR TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ACC_DRAG	V95A0160CC	DRAG DECEL	TAEM UPP	FT/S2			93017G	*
ACC_VERT	V95A0170CD	VERTICAL ACCEL IN TOPODETTIC COORD	TAEM UPP	FT/S2				
ALPHA	V95H3021C	GN&C ANGLE OF ATTACK	ADTA SOP	DEG	SPL		93017G	*
ALT_WHEELS	V95H0165CC	ALT TO REAR WHEELS/NAV BASE(ENTRY)	TAEM UPP	FT	DPL		93017G	*
AUTOP_IND/AUTOP_LAMP	V90X1632XA	PITCH AUTO FLAG	AEROJET DAP				92522D	
AUTORY_IND/AUTORY_LAMP	V90X1642XA	ROLL/YAW AUTO FLAG	AEROJET DAP				92522D	
BAILOUT_FLAG	V90X8654X	BAILOUT FLAG	MSC				89599C	
COSPHI	V90H2204C	EULER ANGLE ROLL COSINE	A/E ATT PROC					
COSTH	V90H2215C	EULER ANGLE PITCH COSINE	A/E ATT PROC				93090E	
COURSE_WRT_RW/PSD	V95H0225CB	COURSE WRT RW CENTERLINE	TAEM UPP	DEG			93017G	*
DEF_AD	V95X3148X	DEFAULT AIR DATA FLAG	ADTA SOP		BD		93017G	*
ENT_PT_SW/NEP	V93X4466X	ENTRY POINT SWITCH CMD	HORIZ SIT DISP		BD		89250B	
FLT_PATH_ANG/GAMMA	V95H0261CA	GROUND-REL FLT PATH ANGLE	TAEM UPP	SPECIAL			93017G	*
GI_CHANGE	V93X4476X	HEAD WIND HI/LO CMD	HORIZ SIT DISP		BD		93017G	*
H_DOT_ELLIPSOID/H_DOT	V95L0265CB	EST ALTITUDE RATE	TAEM UPP	FT/S	SPL		93017G	*
M/CURR_ORB_MASS/MASS	V90U1961CC	CURRENT VEHICLE MASS	DEORB GUID	SLUGS			93090E	
M/MACH	V95L3029C	GN&C MACH NUMBER	ADTA SOP		SPL		93017G	*
PHI/PHI_TOPO	V90H2202C	BODY ROLL ATTITUDE EULER ANGLE	A/E ATT PROC	DEG	SPL		93017G	*
POSN_WRT_RW(1)/X	V95H0220CC	DOWNRANGE DISTANCE WRT RW	TAEM UPP	FT			93017G	*
POSN_WRT_RW(2)/Y	V95H0221CC	CROSSRANGE DISTANCE WRT RW	TAEM UPP	FT			93017G	*
PSHA	V95H0181CA	TURN ANG HAC	TAEM UPP	DEG	SPL		93017G	*
PSHA	V95H0181CC	TURN ANG HAC	ENT UPP	DEG	SPL		93017G	*
QBAR/QBAR_AD	V95P3011C	GN&C DYNAMIC PRESSURE	ADTA SOP	LB/FT2	SPL		93017G	*
QBAR_N	V95P3170C	NAV DERIVED DYNAMIC PRESSURE	NAVDAAD SOP	LB/FT2	SPL		93017G	*
Q_ORB/Q	V90R5321CA	SELECTED RGA PITCH RATE	SF	DEG/S			93017G	*
REL_VEL_MAG/V	V95L0151CD	GND REL VEL MAGNITUDE IN M50 SYS	TAEM UPP	FT/S	SPL		93017G	*
RW_ID_UPP/RW_ID	V95U0205CB	INDEX OF CURRENT RW USED FOR UPP	TAEM UPP				90996G	
R_NEP/RTURN	V95U0183CA	HAC RADIUS	ENT UPP	FT			89250B	
VEL_WRT_RW(1)/XDOT	V95L0255CA	DOWNRANGE VEL WRT RW	TAEM UPP	FT/S			93017G	*
VEL_WRT_RW(2)/YDOT	V95L0256CB	CROSSRANGE VEL WRT RW	TAEM UPP	FT/S			93017G	*
V_GROUNDSPEED/VH	V95L0178CC	GROUNDSPEED	TAEM UPP	FT/S			92389C	
YSGNP/YSGN	V95J0153CB	R/L CONE IND PRI RW	TAEM UPP		SPL		93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.6.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
BAILOUT_ARM	V90X1141XA	BAILOUT ARM FLAG	VERT SIT1 DISP				89250B	
BAILOUT_BANK	V90X1147XA	BAILOUT BANK FLAG	VERT SIT2 DISP				89250B	
BAILOUT_PITCH	V90X1145XA	BAILOUT PITCH FLAG	VERT SIT1 DISP				89250B	
DHDRRF	V90H1110CA	TANGENT OF REF FLIGHT PATH ANGLE	VERT SIT2 DISP					
DPSAC	V90H1111CA	HDG ERROR FROM TANGENCY WITH HAC	TLM					
			DL FMT 23/1	DEG			93017G	*
			E/L ADI PROC					
			ENT BRG SPEC					
DSBC_AT	V90H1011CC	SPEEDBRAKE ANGLE COMMAND-AUTO LAND	AEROJET DAP	DEG			93017G	*
			DL FMT 23/1					
			SPI PROC					
			VERT SIT DIP					
EAS_CMD	V90L1104CA	GUID COMMANDED EAS	DL FMT 23/A	KT			93017G	*
EMAX	V90U1229CA	UPPER E/W REF FOR NZC LIMITING	VERT SIT DIP	FT				
EMEP	V90U1227CA	E/W REF FOR MEPALERT	VERT SIT DIP	FT				
EMIN	V90U1228CA	LOWER E/W REF FOR NZC LIMITING	VERT SIT DIP	FT				
EMOH	V90U1232CA	E/W REF FOR OHALRT	VERT SIT DIP	FT				
EN	V90U1225CA	REFERENCE ENERGY OVER WEIGHT	VERT SIT DIP	FT				
EOW	V90U1231CA	ENERGY OVER WEIGHT	VERT SIT DIP	FT				
EOWNZLL	V90A1113CA	ENERGY LOWER LIMIT-NORM ACCEL CMD	TLM	G				
EOWNZUL	V90A1114CA	ENERGY UPPER LIMIT-NORM ACCEL CMD	TLM	G				
ES	V90U1226CA	E/W REF FOR S-TURN INITIATION	VERT SIT DIP	FT				
GUID_ACCEPT	V90X1200XB	AUTO PTI ACCEPTABLE DISCRETE	PTI				89740B	
HERROR	V90H1115CA	ALTITUDE ERROR	E/L ADI PROC	FT			90960E	
			ENT AREA NAV					
			HORIZ SIT SPEC					
			HUD PROC					
			TLM					
HREF	V90H1116CA	REFERENCE ALTITUDE	TLM	FT				
IGI	V90J1047CA	GROUND INTERCEPT INDEX	HUD PROC					
IGS	V90J1230CA	GLIDESLOPE INDEX	DL FMT 23/1		HXS		93017G	*
			HUD PROC					
			VERT SIT DIP					
IPHASE	V90J1117CA	TAEM GUIDANCE PHASE INDICATOR	DL FMT 23/A	ND			93017G	*
			E/L ADI PROC					
			ENT AREA NAV					
			ENT BRG SPEC					
			HORIZ SIT SPEC					
			HUD PROC					
			MEDS FC GNC XFER					
			TAEM UPP					
			VERT SIT DIP					
MEDS_DPSAC	V90H3907CA	MEDS DISPLAY HEADING ERROR	MEDS FC GNC XFER	DEG	SPL		92522D	

TABLE 4.6.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
MEPALERT	V90X1105XA	MEP ALERT STATUS	DL FMT 23/A GAX				93017G	*
NEP_FB	V90X1109XB	NEP/MEP FLAG	DL FMT 23/A E/L ADI PROC HORIZ SIT SPEC				93017G	*
NZC	V90A1025CB	NORMAL ACCEL CMD	AEROJET DAP DL FMT 23/A GAX	G			93017G	*
OHALERT	V90X1131XA	TAEM GUID DOWNMODE FLAG	HORIZ SIT DISP				90881A	
PHAVG	V90H1118CA	AVG ROLL ANGLE DURING ACQ TURN	TLM	DEG				
PHIC	V90H1031CC	UNLIMITED ROLL COMMAND	TLM	DEG			90881A	
PHIC_AT	V90H1044CB	COMMANDED ROLL ANGLE	A/L GUID AEROJET DAP DL FMT 23/A E/L ADI PROC	DEG			93017G	*
PSC	V90H1234CA	HDG CORR-HAC CNTR TO HAC TAN	ENT AREA NAV	DEG				
PST	V90H1235CA	HEADING TO HAC TANGENCY	ENT AREA NAV	DEG				
QBD	V90P1119CA	FILTERED DYNAMIC PRESSURE RATE	TLM	LB/FT2/S			90185A	
QBERR	V90P1120CA	DYNAMIC PRESSURE ERROR	DL FMT 23/1	LB			93017G	*
QBMNZ	V90P1121CA	LOWER LIMIT ON DYNAMIC PRESSURE	TLM	LB/FT2				
QBMXNZ	V90P1122CA	UPPER LIMIT ON DYNAMIC PRESSURE	TLM	LB/FT2				
QBNZLL	V90P1124CA	DYNMC PRESS LWR LMT-NORM ACCEL CMD	TLM	G				
QBNZUL	V90P1125CA	DYNMC PRESS UPR LMT-NORM ACCEL CMD	TLM	G				
QBREF	V90P1126CA	DYNAMIC PRESSURE REFERENCE	DL FMT 23/1	LB			93017G	*
RCIR	V90H1236CA	DISTANCE TO HAC CENTER	ENT AREA NAV	FT				
RDOT	V90R1127CA	RADIAL RATE DEVIATION FROM HAC	TLM	FT/S				
RERRC	V90H1128CA	ROLL CMD COMP-RADIAL ERR FROM HAC	E/L ADI PROC HORIZ SIT SPEC TLM	FT			90960E	
RF	V90H1158CA	FINAL TURN RADIUS OF SPIRAL	ENT AREA NAV HORIZ SIT SPEC	FT			92389C	
RPRED	V90H1103CB	RANGE TO RUNWAY THRESHOLD VIA WP1	DL FMT 23/A ENT AREA NAV ENT BRG SPEC HORIZ SIT SPEC VERT SIT DIP	FT			93017G	*
RTAN	V90H0115CA	STRT LINE DIST TO TANGENCY POINT	E/L ADI PROC HORIZ SIT SPEC	FT			90960E	
RTURN	V90H1159CA	SPIRAL TURN RADIUS	E/L ADI PROC ENT AREA NAV HORIZ SIT SPEC	FT			92389C	
S	V90U1129CA	SIGN OF ROLL COMMAND FOR S-TURN	TLM					

TABLE 4.6.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
TG_END	V90X1108XA	TAEM GUIDANCE TERMINATION FLAG	A/L UPP AEROJET DAP D/L UPP SEQ DL FMT 23/A E/L ADI PROC GN&C/SM-PL IF HORIZ SIT SPEC HUD PROC MEDS FC GNC XFER MSC SPI PROC TAEM UPP VERT SIT DIP VERT SIT2 DISP				93017G	*
XHAC	V90U1146CA	X-COORDINATE OF HAC CENTER	ENT BRG SPEC HORIZ SIT SPEC	FT			93090E	
YERRC	V90H1130CA	ROLL CMD COMP DUE TO LATERAL ERROR	TLM	DEG				
	V90M2853PA	CGGB_C13_FLAG1	DL FMT 23/A				93017G	*
	V90M2940P	CGEB_IDA_LG1_FLAG_WD1_MFE	DL FMT 23/A				93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
ALPCMDL	V99U9964C	DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPE1	V99U9961C	SEC**-1	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPE2	V99U9962C	SEC*G/DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPQL	V99U9963C	DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
CDEQD	V97U0073C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CPMIN	V97U0075C	ND	F	S	D	C	G4.204 G4.9	01 03	ZSU	89979F	
CQDG	V97U0076C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CQG	V97U0077C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CUBIC_C3(1)	V97U0103C	FT**-1	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
CUBIC_C3(2)	V97U0104C	FT**-1	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
CUBIC_C4(1)	V97U0105C	FT**-2	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
CUBIC_C4(2)	V97U0106C	FT**-2	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
DEL_H1	V97U0113C	ND	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
DEL_H2	V97U0114C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
DEL_R_EMAX(1)	V97U0115C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DEL_R_EMAX(2)	V97U0116C	FT	F	S	M	C	G4.9	00	ZFU	89979F	
DHOH1	V96U8639C	ND	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DHOH2	V96U8640C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DHOH3	V96U8641C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DNZCDL	V97U0122C	G/SEC	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZCG	V97U0123C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZLC1	V97U0124C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
DNZLC2	V97U0125C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZUC1	V97U0126C	G	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
DNZUC2	V97U0127C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DR3	V97U0136C	FT	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
DR4	V96U8635C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	93090E	
DRFK	V96U8663C	ND	F	S	D	X	G5.27 G4.204 G4.9	00	ZSU	93090E	
DSBCM	V97U0131C	ND	F	S	D	C	G5.27 G4.204 G4.36 G4.9	01 03	ZF8	89674E	
DSBLIM	V97U0133C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBLLS	V96U8664C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBNOM	V97U0134C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBSUP	V97U0135C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
DSBULS	V96U8665C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
EDELC1	V97U0142C	ND	F	S	M	X	G4.204 G4.9	00	ZSU	93090E	
EDELC2	V97U0143C	ND	F	S	M	X	G5.27 G4.204 G4.9	00	ZSU	93090E	
EDELNZ(1)	V97U0144C	FT	F	S	M	C	G5.27 G4.204 G4.9	01 03	ZFU	93090E	
EDELNZ(2)	V97U0145C	FT	F	S	M	C	G4.9	00	ZFU	89979F	
EDOTSBG	V97U0194C	DEG*SEC/FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EDRS(1)	V97U0146C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EDRS(2)	V97U0150C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EDSMGAN	V97U0190C	ND	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EMEP_C1(1,1)	V97U0161C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
EMEP_C1(1,2)	V97U0162C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EMEP_C1(2,1)	V97U0164C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EMEP_C1(2,2)	V97U0165C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EMEP_C2(1,1)	V97U0167C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EMEP_C2(1,2)	V97U0168C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EMEP_C2(2,1)	V97U0170C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EMEP_C2(2,2)	V97U0171C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EMOHC1(1)	V96U8666C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EMOHC1(2)	V96U8667C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EMOHC2(1)	V96U8668C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EMOHC2(2)	V96U8669C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
ENBIAS	V96U8670C	FT	F	S	D	C	G4.9	00	ZSU	89979F	
EN_C1(1,1)	V97U0173C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C1(1,2)	V97U0174C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C1(2,1)	V97U0177C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EN_C1(2,2)	V97U0178C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EN_C2(1,1)	V97U0181C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C2(1,2)	V97U0182C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C2(2,1)	V97U0185C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EN_C2(2,2)	V97U0186C	ND	F	S	M	C	G4.9	00	GT3	DC2431A	
EOWSBG	V97U0192C	DEG/FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EOW_SPT(1)	V97U0199C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EOW_SPT(2)	V97U0200C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
EQLOWL	V96U8671C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
EQLOWU	V96U8642C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
ES1(1)	V97U0219C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
ES1(2)	V97U0223C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
ESHFMX	V96U8643C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
GAMMA_COEF1	V97U0230C	DEG/FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
GAMMA_COEF2	V97U0231C	DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
GAMSGS(1)	V97U0236C	DEG	F	S	M	P	G4.204 G4.9	01 03	XS3 XS3	DC0599	
GAMSGS(2)	V97U0237C	DEG	F	S	M	P	G4.9	00	XS3	DC0599	
GDHC	V97U0238C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHLL	V97U0239C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHS	V97U0240C	FT**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHUL	V97U0241C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEHDLL	V97U0242C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEHDUL	V97U0243C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GELL	V97U0244C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEUL	V97U0245C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GMAXB	V97U0166C	G	F	S	M	C	G4.9	00	GT3	DC2431A	
GMAXLL	V97U0179C	G	F	S	M	C	G4.9	00	GT3	DC2431A	
GMAXS	V97U0172C	G/SLUG	F	S	M	C	G4.9	00	GT3	DC2431A	
GMAXUL	V97U0180C	G	F	S	M	C	G4.9	00	GT3	DC2431A	
GPHI	V97U0246C	ND	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
GR	V97U0247C	DEG/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GRDOT	V97U0253C	DEG*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GSBE	V97U0257C	DEG/(LBS/FT**2)	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GY	V97U0263C	DEG/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GYDOT	V97U0264C	DEG*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
HALI(1)	V97U0287C	FT	F	S	D	C	G4.220 G4.9	00	ZFU	89979F	
HALI(2)	V97U0288C	FT	F	S	D	C	G4.220 G4.9	00	ZFU	89979F	
HBLEND	V97U0187C	FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
HDREQG	V97U0290C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
HFTC(1)	V97U0291C	FT	F	S	D	C	G4.204 G4.220 G4.237 G4.9	01 03	ZFU ZFU	89979F	
HFTC(2)	V97U0292C	FT	F	S	D	C	G4.220 G4.9	00	ZFU	89979F	
HGAINSB	V97U0188C	FT**-1	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
HMEP(1)	V96U8636C	FT	F	S	D	C	G4.204 G4.220 G4.237 G4.9	01 03	ZFU ZFU	89979F	
HMEP(2)	V96U8637C	FT	F	S	D	C	G4.220 G4.9	00	ZFU	89979F	
H_MIN_3	V96U8305C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
H_REF1	V97U0279C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
H_REF2	V97U0280C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
P2TRNC1	V97U0351C	ND	F	S	D	C	G4.103 G4.204 G4.9 G5.7	00	ZSU	90960E	
PBGC(1)	V97U0327C	ND	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBGC(2)	V97U0328C	ND	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBHC(1)	V97U0329C	FT	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBHC(2)	V97U0330C	FT	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBRC(1)	V97U0331C	FT	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBRC(2)	V97U0332C	FT	F	S	M	C	G4.220 G4.9	00	GT3	DC2431A	
PBRCQ(1)	V97U0333C	FT	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
PBRCQ(2)	V97U0334C	FT	F	S	M	C	G4.9	00	GT3	DC2431A	
PEWRR	V96U8645C	ND	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
PHAVGC	V97U0335C	DEG	F	S	D	X	G4.204 G4.220 G4.237 G4.9 G5.27	00	ZSU	93090E	
PHAVGLL	V97U0336C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PHAVGS	V97U0337C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PHAVGUL	V97U0338C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PHI2C1	V96U7838C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHI2C2	V96U7839C	DEG** -1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILM0	V97U0343C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM1	V97U0344C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM2	V97U0345C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM3	V97U0346C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILM4	V96U8674C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILMSUP	V97U0342C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILR1	V99U7406C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILR2	V99U7407C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILS	V96U8644C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHIM	V97U0347C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PQBWRR	V96U8646C	LB/FT**3	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
PSHARS	V96U8647C	DEG	F	S	D	C	G4.19	01	ZFU	93090E	
							G4.20	03	ZFU		
							G4.204				
							G4.220				
							G4.23				
							G4.237				
							G4.24				
							G4.25				
							G4.9				
							G5.27				
PSOHAL	V96U8649C	DEG	F	S	D	X	G4.204	00	ZSU	89979F	
PSOHAL	V96U8649C	DEG	F	S	D	X	G4.9				
PSOQB	V96U8650C	DEG	F	S	D	X	G4.204	00	ZSU	89979F	
PSOQB	V96U8650C	DEG	F	S	D	X	G4.9				
PSRF	V96U8648C	DEG	F	S	D	X	G4.204	00	ZSU	93090E	
PSRF	V96U8648C	DEG	F	S	D	X	G4.9				
PSRF	V96U8648C	DEG	F	S	D	X	G5.27				
PSSTRN	V96U8651C	DEG	F	S	D	C	G4.204	01	ZFU	89979F	
PSSTRN	V96U8651C	DEG	F	S	D	C	G4.9	03	ZFU		
QBARDL	V97U0355C	LBS/FT**2/SEC	F	S	D	C	G4.204	01	ZFU	89979F	
QBARDL	V97U0355C	LBS/FT**2/SEC	F	S	D	C	G4.9	03	ZFU		
QBC1(1)	V97U0356C	LBS/FT**2/FT	F	S	M	C	G4.204	01	GT1	DC2431A	
QBC1(1)	V97U0356C	LBS/FT**2/FT	F	S	M	C	G4.9	03	GT3		
QBC1(2)	V97U0357C	LBS/FT**2/FT	F	S	M	C	G4.9	00	GT3	DC2431A	
QBC2(1)	V97U0358C	LBS/FT**2/FT	F	S	M	C	G4.204	01	GT1	DC2431A	
QBC2(1)	V97U0358C	LBS/FT**2/FT	F	S	M	C	G4.9	03	GT3		
QBC2(2)	V97U0359C	LBS/FT**2/FT	F	S	M	C	G4.9	00	GT3	DC2431A	
QBG1	V97U0360C	SEC**-1	F	S	D	C	G4.204	01	ZFU	89979F	
QBG1	V97U0360C	SEC**-1	F	S	D	C	G4.9	03	ZFU		
QBG2	V97U0361C	SEC*/LBS/FT**2	F	S	D	C	G4.9	00	ZSU	89979F	
QBM1	V97U0371C	ND	F	S	D	X	G4.204	00	ZSU	89979F	
QBM1	V97U0371C	ND	F	S	D	X	G4.9				
QBM2	V97U0372C	ND	F	S	D	X	G4.204	00	ZSU	89979F	
QBM2	V97U0372C	ND	F	S	D	X	G4.9				
QBMSL1	V96U8654C	LBS/(SLUG*FT**2)	F	S	D	X	G4.204	00	ZSU	89979F	
QBMSL1	V96U8654C	LBS/(SLUG*FT**2)	F	S	D	X	G4.9				
QBMSL2	V96U8655C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204	01	ZFU	89979F	
QBMSL2	V96U8655C	LBS/(SLUG*FT**2)	F	S	D	C	G4.9	03	ZFU		
QBMX1	V97U0367C	LBS/FT**2	F	S	D	X	G4.204	00	ZSU	89979F	
QBMX1	V97U0367C	LBS/FT**2	F	S	D	X	G4.9				
QBMX2	V97U0368C	LBS/FT**2	F	S	D	C	G4.204	01	ZFU	89979F	
QBMX2	V97U0368C	LBS/FT**2	F	S	D	C	G4.9	03	ZFU		
QBMX3	V97U0369C	LBS/FT**2	F	S	D	C	G4.204	01	ZFU	89979F	
QBMX3	V97U0369C	LBS/FT**2	F	S	D	C	G4.9	03	ZFU		
QBMXS1	V96U8676C	LBS/FT**2	F	S	D	C	G4.204	01	ZFU	89979F	
QBMXS1	V96U8676C	LBS/FT**2	F	S	D	C	G4.9	03	ZFU		

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
QBMXS2	V97U0366C	LBS/FT**2	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBREF2(1)	V96U8652C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
QBREF2(2)	V96U8653C	LBS/FT**2	F	S	M	C	G4.9	00	GT3	DC2431A	
QBRLL(1)	V97U0373C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
QBRLL(2)	V97U0374C	LBS/FT**2	F	S	M	C	G4.9	00	GT3	DC2431A	
QBRML(1)	V97U0375C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
QBRML(2)	V97U0376C	LBS/FT**2	F	S	M	C	G4.9	00	GT3	DC2431A	
QBRUL(1)	V97U0377C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
QBRUL(2)	V97U0378C	LBS/FT**2	F	S	M	C	G4.9	00	GT3	DC2431A	
QBWT1	V96U8656C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
QBWT2	V96U8657C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
QBWT3	V96U8658C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
QB_ERROR2	V97U0354C	LBS/FT**2	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
QMACH1	V96U8659C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QMACH2	V96U8660C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
R1	V96U8263C	FT/DEG	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27 G5.7	00	ZSU	93090E	
R2	V96U8264C	FT/DEG**2	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27 G5.7	00	ZSU	93090E	
R2MAX	V96U8673C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
RERRLM	V97U0384C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
RFMN	V96U8661C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	93090E	
RFMX	V96U8662C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
RFO	V96U8262C	FT	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27 G5.7	00	ZSU	93090E	
RFTC	V97U0385C	SEC	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
RMINST(1)	V97U0387C	FT	F	S	M	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
RMINST(2)	V97U0388C	FT	F	S	M	C	G4.9	00	ZSU	89979F	
RMOH	V96U8672C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
TGGS(1)	V97U0414C	ND	F	S	M	C	G4.220 G4.9	00	XS3	DC0599	
TGGS(2)	V97U0415C	ND	F	S	M	C	G4.220 G4.9	00	XS3	DC0599	
VERTACLIMIT	V99U6337C	FT/SEC**2	F	S	M	P	G4.9	00	PTI	DC0599	
V_DEF	V97U0536C	FT/SEC	F	S	M	P	G4.204 G4.9	00	ZSU	89979F	
WT_GS1	V97U0444C	SLUGS	F	S	M	C	G4.10 G4.220 G4.23 G4.24 G4.25 G4.9 G5.27	00	GLC	93090E	
XA(1)	V97U0456C	FT	F	S	M	X	G4.204 G4.220 G4.237 G4.9	00	XS3	DC0599	
XA(2)	V97U0457C	FT	F	S	M	X	G4.204 G4.220 G4.237 G4.9	00	XS3	DC0599	

TABLE 4.6.3-3. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
YERRLM	V97U0464C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
Y_RANGE1	V97U0462C	ND	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
Y_RANGE2	V97U0463C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.6.3-4. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
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NO REQUIREMENTS

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.6.3-5. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S	C A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DTG TIME STEP BETWEEN TAEM GUIDANCE CALLS	V97U6116C	00	+9.6	E-01 SEC	F		S	C G4.204 G4.9	90374C	

TABLE 4.6.3-5. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S P	A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	

TABLE 4.6.3-5. TERMINAL AREA ENERGY MANAGEMENT GUIDANCE (G4.9) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
RAD_PER_DEG DEGREE TO RADIAN CONVERSION FACTOR	V97U0383C	00	+1.7453293	E-02	RAD/DEG	F	S	C A6.9 G4.1 G4.126 G4.127 G4.128 G4.144 G4.15 G4.158 G4.175 G4.20 G4.201 G4.204 G4.205 G4.209 G4.210 G4.211 G4.213 G4.220 G4.223 G4.226 G4.227 G4.236 G4.237 G4.3 G4.35 G4.36 G4.7 G4.72 G4.9 G4.97 G5.27	93090E	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

4.7 APPROACH AND LANDING (MAJOR MODE 305)

The approach and landing guidance/control phase (A/L) begins with completion of the terminal area energy management (TAEM) guidance/control phase and ends when the vehicle comes to a complete stop on the runway.

4.7.1 Requirements Overview

This phase contains guidance functions necessary to steer the orbiter to the runway for touchdown and rollout. Figure 4.7.1-1 shows the guidance function structure for A/L. The approach and landing guidance module executes the longitudinal guidance and lateral guidance modules.

The function of the longitudinal guidance module (Section 4.7.2.1) is to execute functions which:

1. Compute a normal acceleration command as output to the flight control subsystem (FC) and displays.
2. Compute a speed brake command as output to FC and displays.
3. Issue a retract body flap command to FC below a predetermined altitude or at A/L initiation.
4. Issue commands to arm and deploy the landing gear and drag chute during a Remote Control Orbiter (RCO) landing.

The function of the lateral guidance module (Section 4.7.2.2) is to execute functions which:

1. Compute a roll-attitude command as output to FC and displays.
2. Compute a wings-level roll command during flat turn.
3. Compute a yaw-rate command as output to FC during flat turn, touchdown, and rollout.

Auxiliary functions that have common usage to approach and landing guidance, indicated on Figure 4.7.1-1, are discussed in Section 4.7.2.

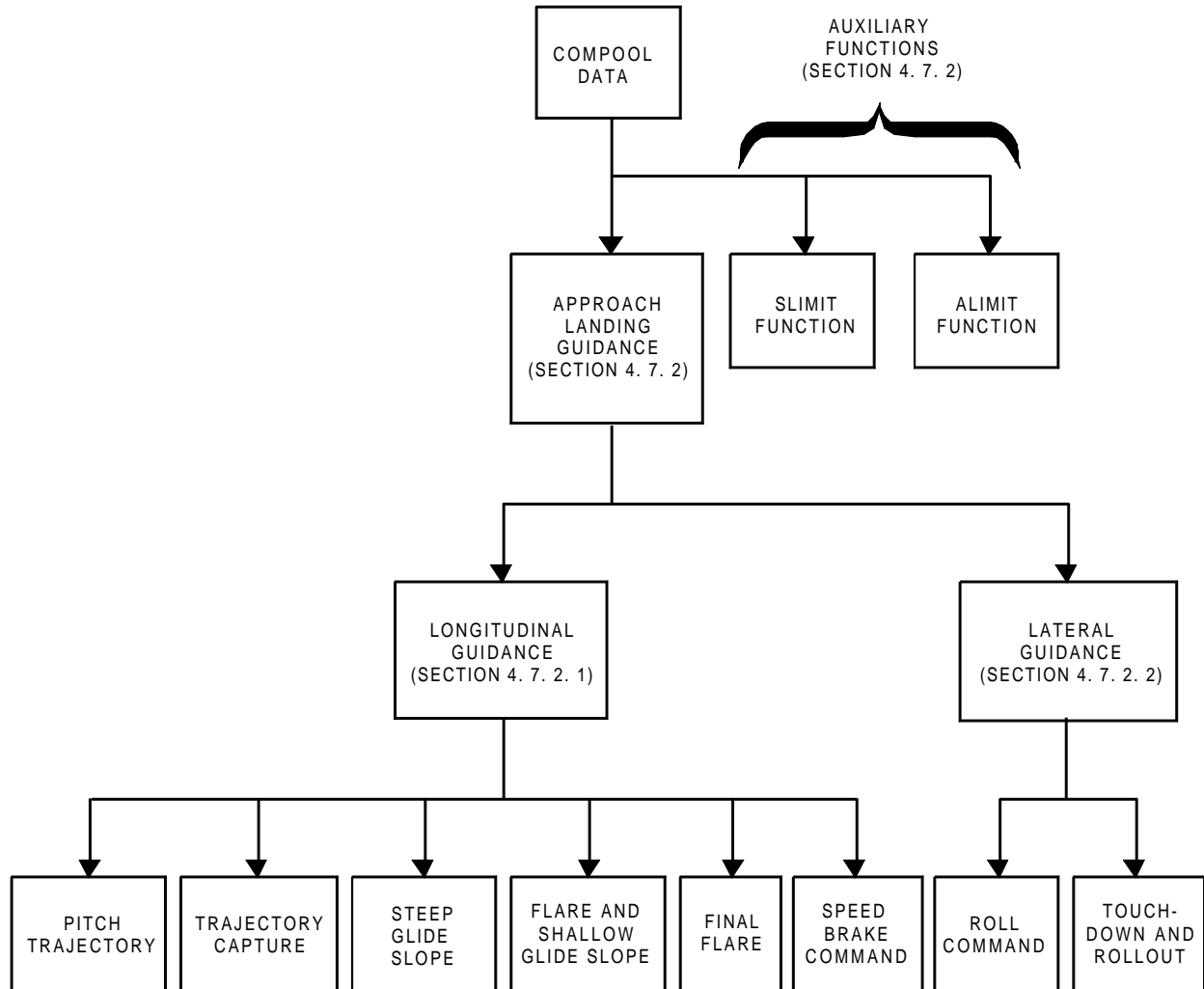


FIGURE 4.7.1-1. Approach and Landing Guidance Function Structure

4.7.2 Approach and Landing Guidance (G4.10)

The approach and landing phase (A/L) begins with the termination of the terminal area energy management (TAEM) phase and ends when the vehicle comes to a complete stop on the runway. The A/L guidance issues longitudinal and lateral commands to enable the vehicle to acquire and maintain a landing approach trajectory from TAEM guidance termination to touchdown. Normal acceleration, roll–attitude, and speed–brake–position commands are output to maintain the specified trajectory while the vehicle is airborne. Yaw–rate and wings–level roll attitude commands are issued during flat turn, touchdown, and roll–out to track the runway centerline. During all phases, the orbiter state vector is updated by the navigation subsystem. In the approach phase, the state vector computation may be augmented by additional information from a microwave scanning beam landing system (MSBLS). The availability of MSBLS data represents an A/L system requirement to ensure accurate and reliable guidance command processing. A/L guidance command processing is continued with the flight control subsystem operating in the CSS mode in the pitch and/or roll/yaw axes. In the event a Remote Control Orbiter (RCO) contingency scenario has been declared, an auto landing will be attempted since no crew is aboard the Orbiter. During this scenario, A/L guidance generates additional commands to arm and deploy the landing gear and drag chute subsystems at certain trajectory events. Automation of these capabilities is necessary since these functions are normally performed by the flight crew.

A/L guidance is partitioned into two functional modes that are operational throughout all subphases: longitudinal guidance and lateral guidance. The input parameters for A/L guidance are derived from the navigation, flight control, and air data subsystems, as well as displays. Output parameters are issued to flight control and displays. During the RCO scenario, additional parameters are issued to the Systems Management (SM) GPC.

A. Detailed Requirements. A/L guidance is divided into two functions: longitudinal guidance and lateral guidance. The logical process for A/L guidance is as follows:

1. Process Set 1.
 - 1.1 Process Longitudinal Guidance (Section 4.7.2.1).
 - 1.2 Process Lateral Guidance (Section 4.7.2.2).

B. Interface Requirements. The input/output parameters and I–loads/constants for each software function within A/L guidance are shown in each subsection describing the function. Equivalent internal names for external input parameters are shown in Table 4.7.2–1 as will then be reflected in subsequent detailed requirements.

C. Processing Requirements. Processing of A/L guidance must be executed once each guidance cycle throughout the A/L major mode phase. All arithmetic computations are to be done in single precision.

D. Initialization Requirements. At the TAEM–A/L transition, the A/L guidance program is executed before the flight control program in the new phase.

E. Supplemental Information. Throughout A/L phase, functions of Figure 4.7.2–1 are used. These are of three types: (1) trigonometric of high order articulated language (HAL) common usage with single argument, (2) ancillary function blocks with one or more arguments, and (3) Z–transform type requiring storage of previously computed inputs or outputs of the function.

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Functional flow charts for the Approach/Landing Guidance are provided in section 5.1.3 to assist in understanding the function logic. In case of conflict between the flow charts in section 5.1.3 and the requirements in Section 4.7.2, the requirements in Section 4.7.2 shall have precedence.

Table 4.7.2-1. Approach and Landing Guidance Input/Internal Name Equivalents				
MSID	Source Input Name	Internal Name	Description	Source
V90H1044CB	PHIC_AT	PHIC_AT	Commanded roll angle	TAEM GUID
V90U1961CC	M	MASS	Current vehicle mass	DEORB GUID
V95L0178CD	V_GROUNDSPEED	V_G	Groundspeed	A/L UPP
V95H0220CD	POSITION_WRT_RUNWAY(1)	X	Downrange distance wrt RW	A/L UPP
V95H0221CD	POSITION_WRT_RUNWAY(2)	Y	Cross range distance wrt RW	A/L UPP
V95L0256CA	VELOCITY_WRT_RUNWAY(2)	Y_DOT	Cross range vel wrt RW	A/L UPP
V95L0151CB	REL_VEL_MAG	V_I	Ground rel vel magnitude	A/L UPP
V95H0261CB	FLT_PATH_ANG	GAMMA	Ground rel flight path angle	A/L UPP
V95H0225CC	COURSE_WRT_RW	PSI_GND	Course wrt RW center line	A/L UPP
V95L0265CC	H_DOT_ELLIPSOID	H_DOT	Estimated altitude rate	A/L UPP
V95H0165CD	ALT_WHEELS	H	Alt to rear wheels	A/L UPP
V90X1632XA	AUTOP_LAMP	AUTOP_LAMP	Pitch auto flag	AEROJET DAP
V90X1642XA	AUTORY_LAMP	AUTORY_LAMP	Roll/yaw auto flag	AEROJET DAP
V95L3015C	TAS	TAS	GN&C true airspeed	ADTA SOP
V95L3145C	EAS	EAS	GN&C equivalent airspeed	ADTA SOP
V96X0050X	WOWLON_IND	WOWLON	Weight on main wheels ind	LANDING SOP
V96X0051X	FLATTURN_CMD	FLATTURN	Flatturn indicator	LANDING SOP
V93X4476X	GI_CHANGE	GI_CHANGE	Head wind high/low cmd (a.k.a. steep glide slope ground intercept redesignation flag)	HORIZ SIT DISP
V95P3011C	QBAR	QBAR	GN&C dynamic pressure	ADTA SOP
V93J0996C	I_SHORT_RW	I_SHORT_RW	Short runway option	HORIZ SIT DISP
V93X1112X	RCO_ENABLE	RCO_ENABLE	RCO Inhibit/Enable Command	RM SWITCH/ SURF FB DISP

Function	Designations
<p>Y = INTEGRAL (X)</p>	<p>Z - Transform:</p> $Y = \frac{T}{1 - Z^{-1}} X$ <p>where T = A/L guidance sample time interval = .16 sec</p>
<p>Y = LAG_FILTER (A, X)</p>	<p>Z - Transform:</p> $Y = \frac{1 - \text{EXP}(-A T)}{1 - Z^{-1} \text{EXP}(-A T)} X$ <p>where T = A/L guidance sample time interval = .16 sec</p>
<p>Y = SLIMIT (X, A)</p>	$Y = \begin{cases} -A, & X < -A \\ X, & -A \leq X \leq A \\ A, & X > A \end{cases}$ <p>where A > 0</p>
<p>Y = ALIMIT (X, A, B)</p> <p>Note: ALIMIT is equivalent to the HAL/S MIDVAL function</p>	$Y = \begin{cases} A, & X < A \\ X, & A \leq X \leq B \\ B, & X > B \end{cases}$ <p>where B > A</p>
$Y = \begin{cases} \text{ARCSIND}(X) \\ \text{ARCTAND}(X) \\ \text{SIND}(X) \\ \text{COSD}(X) \\ \text{TAND}(X) \end{cases}$	$Y = \begin{cases} K \text{ ARCSIN}(X) \\ K \text{ ARCTAN}(X) \\ \text{SIN}(X/K) \\ \text{COS}(X/K) \\ \text{TAN}(X/K) \end{cases}$ <p>where K = radian to degrees conversion factor</p>
<p>Y = LN(X)</p>	<p>Y = natural log of X</p>

FIGURE 4.7.2-1. Auxiliary Function Designations

4.7.2.1 Longitudinal Guidance.

A/L longitudinal guidance is divided into four subphases:

- Trajectory capture
- Steep glide slope
- Flare and shallow glide slope
- Final flare

Switching control between subphases is made internal to each subphase function by change of subphase flag when subphase switching conditions are satisfied.

Trajectory capture, the first subphase, is entered at the beginning of A/L guidance. Its purpose is to acquire and steer into the steep glide slope trajectory. The steep glide slope subphase commences when the trajectory capture subphase is completed. The linear steep glide slope trajectory is tracked until the altitude-dependent initiation of the flare and shallow glide slope subphase. The orbiter is then maneuvered from the steep glide slope to the shallow glide slope; the shallow glide slope is tracked until the altitude- and velocity-dependent final flare subphase is initiated. The final flare subphase continues until the weight-on-wheels (WOWLON) event. Once the weight-on-wheels (WOWLON) event occurs, longitudinal guidance command operations for derotation, load balancing, and slapdown become exclusively an FCS function (Refer to STS 83-0007).

The function of longitudinal guidance during the A/L trajectory phases is as follows:

1. To provide normal acceleration command NZC to flight control subsystems.
2. To provide speed brake position command DSBC_AL to flight control subsystem and displays.
3. To issue a retract body flap flag discrete (RETRACT_BF = TRUE) to flight control subsystem below a predetermined altitude or at A/L initiation.
4. To issue landing gear and drag chute arm and deploy commands to the SM GPC during an RCO landing.

A. Detailed Requirements. Longitudinal guidance is divided into the six subfunctions in Table 4.7.2.1-1. The logical processes of calling these subfunctions are as follows (Figure 4.7.2.1-1):

1. The Pitch Trajectory subfunction (Section 4.7.2.1.1) is executed every A/L guidance cycle prior to any other longitudinal guidance subfunction.
2. If the subphase mode indicator is set to the trajectory capture value (P_MODE = 1), the Trajectory Capture subfunction is called (Section 4.7.2.1.2).
3. If the subphase mode indicator is set to the steep glide slope value (P_MODE = 2), then the Steep Glide Slope subfunction is called (Section 4.7.2.1.3).
4. If the subphase mode indicator is set to the flare and shallow glide slope value (P_MODE = 3), then the Flare and Shallow Glide Slope subfunction is called (Section 4.7.2.1.4).

5. If the subphase mode indicator is set to the final flare value (P_MODE = 4), then the Final Flare subfunction is called (Section 4.7.2.1.5).
6. The normal acceleration command to the FCS, NZC, is generated from the unlimited normal acceleration command, NZ_C, calculated by the appropriate longitudinal subfunction (trajectory capture, steep glide slope, flare and shallow glideslope, and final flare). The unlimited command is first compensated for a normal acceleration command path transport lag and is then limited by a predetermined value, NZC_LIM, as shown in Equation Set 1.

On the first pass, required initialization of the past value of the unlimited normal acceleration command, NZ_CP, is accomplished using Equation 1.1.

$$1.1 \quad NZ_CP = NZ_C$$

Transport lag compensation and command limiting for NZC as well as updating the past value of NZ_C is accomplished using Equations 1.2 through 1.4.

$$1.2 \quad NZ_COMP = NZ_C + DT_LAG_NZ (NZ_C - NZ_CP) / DT$$

$$1.3 \quad NZC = SLIMIT(NZ_COMP, NZC_LIM)$$

$$1.4 \quad NZ_CP = NZ_C$$

7. The Speed Brake Command subfunction is called (Section 4.7.2.1.6).

B. Interface Requirements. The input and output interface requirements associated with longitudinal guidance are presented in each longitudinal guidance subfunction as referenced above. Input, output, and I-load/constant requirements to support any particular processing at this level are given in Tables 4.7.2.1-2, 4.7.2.1-3, and 4.7.2.1-4, respectively.

C. Processing Requirements. Execution of A/L guidance begins with longitudinal guidance processing.

D. Initialization Requirements. NZ_CP must be initialized on first-pass to NZ_C before processing the transport lag compensation equation.

E. Supplemental Information. Although the A/L guidance normal acceleration command output to the FCS, NZC, was initially intended to reflect a zero value upon detection of touchdown via the weight-on-wheels indicator (ref: Final Flare subfunction), the addition of the Nz command transport lag compensator described above will circumvent this initially baselined design goal. Once weight-on-wheels has occurred, the A/L guidance NZC output will simply sustain the last computed value of NZ_C. In that the Aerojet DAP pitch axis requirements are such that the A/L guidance command is ignored by the FCS upon its acknowledgement of weight-on-wheels, the only “visible” effect of the transport lag compensator “overwrite” is via telemetry data as it will reflect a constant NZC value equal to the last computed value for NZ_C once the weight-on-wheels event is detected by A/L guidance.

A functional flow for the Approach/Landing Longitudinal Guidance function is provided in section 5.1.3.

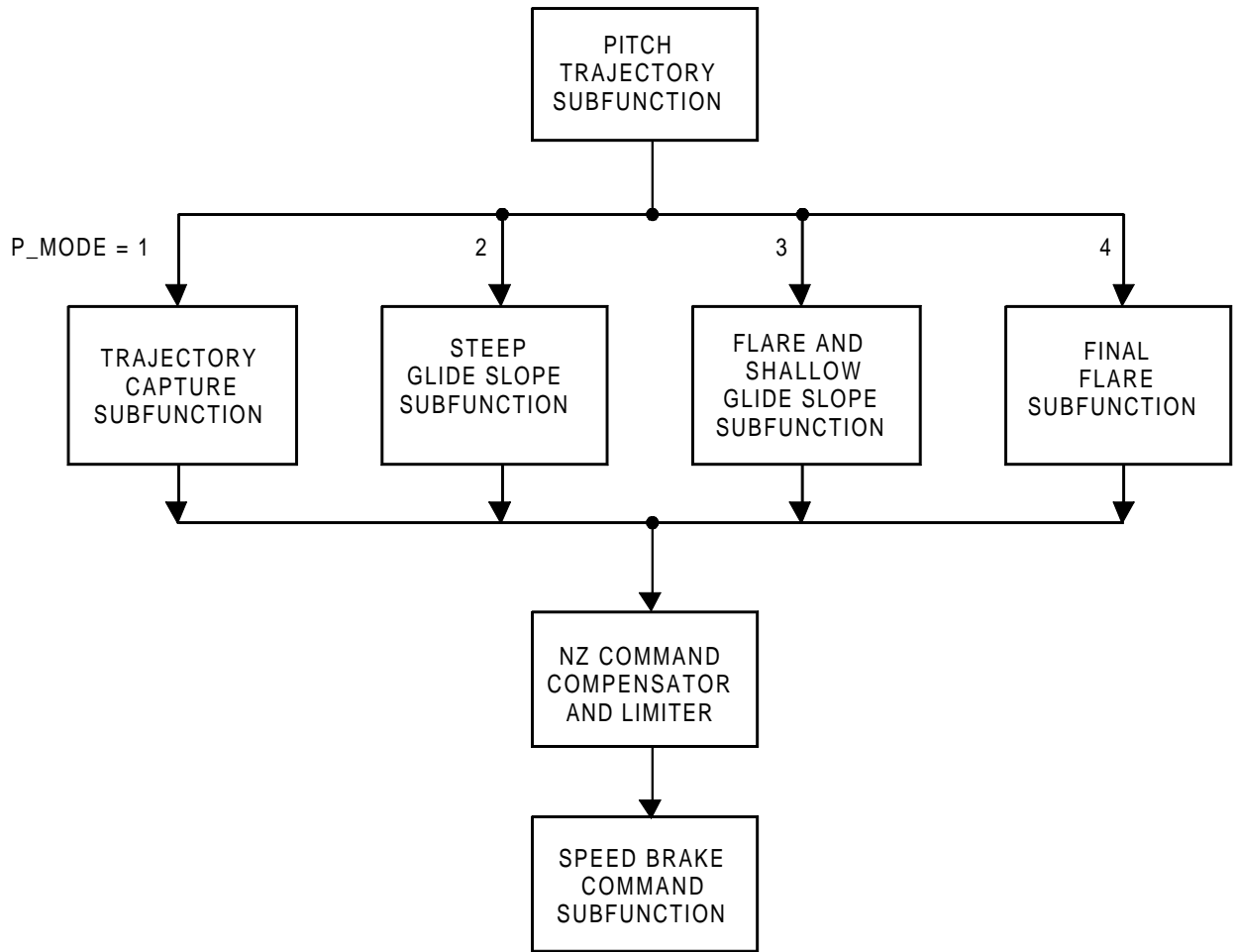


FIGURE 4.7.2.1-1. Longitudinal Guidance Subfunction Sequencing Requirements

Table 4.7.2.1-1. Longitudinal Guidance Subfunction Descriptions		
Subfunction	Section	Description
Pitch Trajectory	4.7.2.1.1	<ol style="list-style-type: none"> 1. Computes variables that are commonly used by successive trajectory subphases. 2. Initializes subphases mode indicator. 3. Initializes body flap retract command discrete (I-load dependent). 4. Issue commands to arm and deploy the landing gear and drag chute during an RCO landing.
Trajectory Capture	4.7.2.1.2	Computes normal acceleration command to guide orbiter to steep glide slope.
Steep Glide Slope	4.7.2.1.3	<ol style="list-style-type: none"> 1. Computes normal acceleration command to guide orbiter along steep glide slope trajectory.
Flare and Shallow Glide Slope	4.7.2.1.4	<ol style="list-style-type: none"> 1. Computes normal acceleration command to guide orbiter from steep to shallow glide slope. 2. Issues discrete for body flap to be positioned for landing.
Final Flare	4.7.2.1.5	<ol style="list-style-type: none"> 1. Computes normal acceleration command to guide orbiter from shallow glide slope to touchdown. 2. Terminates A/L longitudinal guidance trajectory dependent command processing upon sensed touchdown (WOWLON = TRUE).
Speed Brake Command	4.7.2.1.6	<ol style="list-style-type: none"> 1. Computes closed-loop speed brake command to FCS to acquire and maintain reference equivalent air speed on steep glide slope. 2. Computes speed brake retract angle commands for pull-up and landing to provide proper energy for landing.

Table 4.7.2.1-1. Longitudinal Guidance Subfunction Descriptions		
Subfunction	Section	Description
		3. Issue touchdown and roll-out speed brake command at touchdown (WOWLON = TRUE).

Table 4.7.2.1-2. Longitudinal Guidance Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Computation Rate (Hz)
INPUT					
NZ_C	Unlimited normal acceleration command	SGS, FSGS, FF	F	g	6.25
P_MODE	Pitch subphase mode indicator	PT, TC, SGS, FSGS	I	ND	6.25
OUTPUT					
NZC	Normal acceleration command	FC, TLM	F	g	6.25

Table 4.7.2.1-3. Longitudinal Guidance I-Loads/Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V96U9364C	DT_LAG_NZ	Time constant for transport lag compensation		F	sec	SX
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X
V97U0323C	NZC_LIM	Maximum normal acceleration command		F	g	SX

4.7.2.1.1 Pitch Trajectory.

The Pitch Trajectory subfunction of Figure 4.7.2.1.1–1 computes variables that are required by several of the trajectory subphases, initializes all of the longitudinal flags and discretely, determines glide slope selection based on vehicle weight, and checks for redesignation of the steep glide slope ground intercept.

A. Detailed Requirements. When longitudinal guidance is entered, the Pitch Trajectory subfunction computations are made. The process of computing the equations are as follows:

1. On the first pass, required initialization of variables, flags, and discretely is accomplished using Equation Set 1. Also in Equation Set 1, selection of the steep glide slope is performed by setting the steep glide slope index, IGS, based on vehicle weight, and the steep glide slope ground intercept flag, IGI, is set based on the discrete input GI_CHANGE.
 - 1.1 $V_T_FILT = TAS$
 - 1.2 $RETRACT_BF = INIT_RET_BF$
 - 1.3 $P_MODE = P_MODE_INITIAL$
 - 1.4 $IGS = 1$
 - 1.5 If $MASS > WT_GS1$, then $IGS = 2$
 - 1.6 $IGI = 1$
 - 1.7 If $GI_CHANGE = TRUE$, then $IGI = 2$
2. On every pass, the filtered true airspeed (V_T_FILT) is calculated using Equation 2.1. The estimated longitudinal component of the wind is computed using equation 2.2.
 - 2.1 $V_T_FILT = LAG_FILTER(A_{13}, TAS)$
 - 2.2 $V_WIND_X = V_G - V_T_FILT \cos(\arcsin(H_DOT/V_T_FILT))$
3. Figure 4.7.2.1.1–2 shows the reference trajectory geometry for steep and shallow glide slopes. Compute Equation 3.1 on each pass. If the orbiter is tracking the steep glide slope trajectory ($P_MODE = 1$ or 2 or [$P_MODE = 3$ and $F_MODE < 2$]), then the reference trajectory variables [H_REF and $GAMMA_REF$] are computed in Equations 3.2, 3.3, 3.4, and 3.5; otherwise ($[P_MODE = 3$ and $F_MODE > 1]$, or $P_MODE = 4$) compute Equation Set 4.
 - 3.1 $R_GND_AP = \sqrt{(X - X_AIM_PT)^2 + Y^2}$
 - 3.2 $PSI_COR = \arctan(Y/(X - X_AIM_PT))$
 - 3.3 $X_ZERO_COR = (X_ZERO_{IGI} + X_AIM_PT) \cos(PSI_COR)$
 - 3.4 $H_REF = (X_ZERO_COR - R_GND_AP) \tan(GAMMA_REF_{1IGS})$
 - 3.5 $GAMMA_REF = GAMMA_REF_{1IGS}$

$$4.1 \quad H_REF = -R_GND_AP \cdot \tan(\text{GAMMA_REF_2})$$

$$4.2 \quad \text{GAMMA_REF} = \text{GAMMA_REF_2}$$

4. If the subphase mode flag is set to the value for flare and shallow glide slope ($P_MODE = 3$) and the operating mode flag is not pullup initiation ($F_MODE > 1$), then the flight path error from the steep or shallow glide slope (GAMMA_ERROR) is computed in Equation 5.1 and the altitude and altitude rate errors are computed in the FSGS subfunction; otherwise, the flight path error, the altitude error from the steep or shallow glide slope (H_ERROR), and the altitude rate error from the glide slopes (H_DOT_ERROR) are computed in Equation Set 6.

$$5.1 \quad \text{GAMMA_ERROR} = \text{GAMMA_REF} - \text{GAMMA}$$

$$6.1 \quad H_ERROR = H_REF - H$$

$$6.2 \quad \text{GAMMA_ERROR} = \text{GAMMA_REF} - \text{GAMMA}$$

$$6.3 \quad H_DOT_ERROR = V_I \cdot \sin(\text{GAMMA_REF}) - H_DOT$$

5. If the RCO capability has been enabled ($\text{RCO_ENABLE} = \text{ON}$), then the pitch trajectory function will send the landing gear and drag chute arm and deploy commands to the SM GPC via the GN&C/Systems Management - Payload Interface (GN&C/SM-PL IF) principal function based on the criteria in equation set 7.

7.1 If ($\text{RCO_ENABLE} = \text{ON}$), then execute equations 7.2 through 7.4

7.2 If ($H < \text{RCO_H_ARM}$), then $\text{RCO_LG_ARM} = \text{TRUE}$

7.3 If ($H < \text{RCO_H_GEAR}$), then $\text{RCO_LG_DEPLOY} = \text{TRUE}$

7.4 If ($\text{WOWLON} = \text{TRUE}$) and ($\text{EAS} < \text{RCO_EAS_DC}$), then execute equations 7.4.1 and 7.4.2

7.4.1 $\text{RCO_DC_ARM} = \text{TRUE}$

7.4.2 $\text{RCO_DC_DEPLOY} = \text{TRUE}$

B. Interface Requirements. The input/output parameters associated with the Pitch Trajectory processing are presented in Table 4.7.2.1.1-1. The I-loads/constants are presented in Table 4.7.2.1.1-2.

C. Processing Requirements. Execution of longitudinal guidance begins with Pitch Trajectory processing. Processing of Pitch Trajectory must be executed once each guidance cycle throughout the A/L major mode phase.

D. Initialization Requirements. The initialization requirements for the Pitch Trajectory subfunction are shown in Table 4.7.2.1.1-3.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

A review of the overall sequencing requirements for A/L guidance will uncover that Pitch Trajectory use of the flare and shallow glide slope mode flag, F_MODE , is invoked for one execution cycle prior to the

explicit initialization requirement for F_MODE as defined in the FSGS functional requirements specifications. Hence, the software implementor is advised that F_MODE be declared with a value of one or less to insure proper processing of Pitch Trajectory Equation Sets 3 and 4.

As may be gleaned from first pass requirements described in Equation Set 1, any change to the steep glide slope ground intercept redesignation flag status subsequent to the initial PT execution cycle will have zero effect on A/L guidance.

A functional flow for the Approach/Landing Pitch Trajectory function is provided in section 5.1.3.

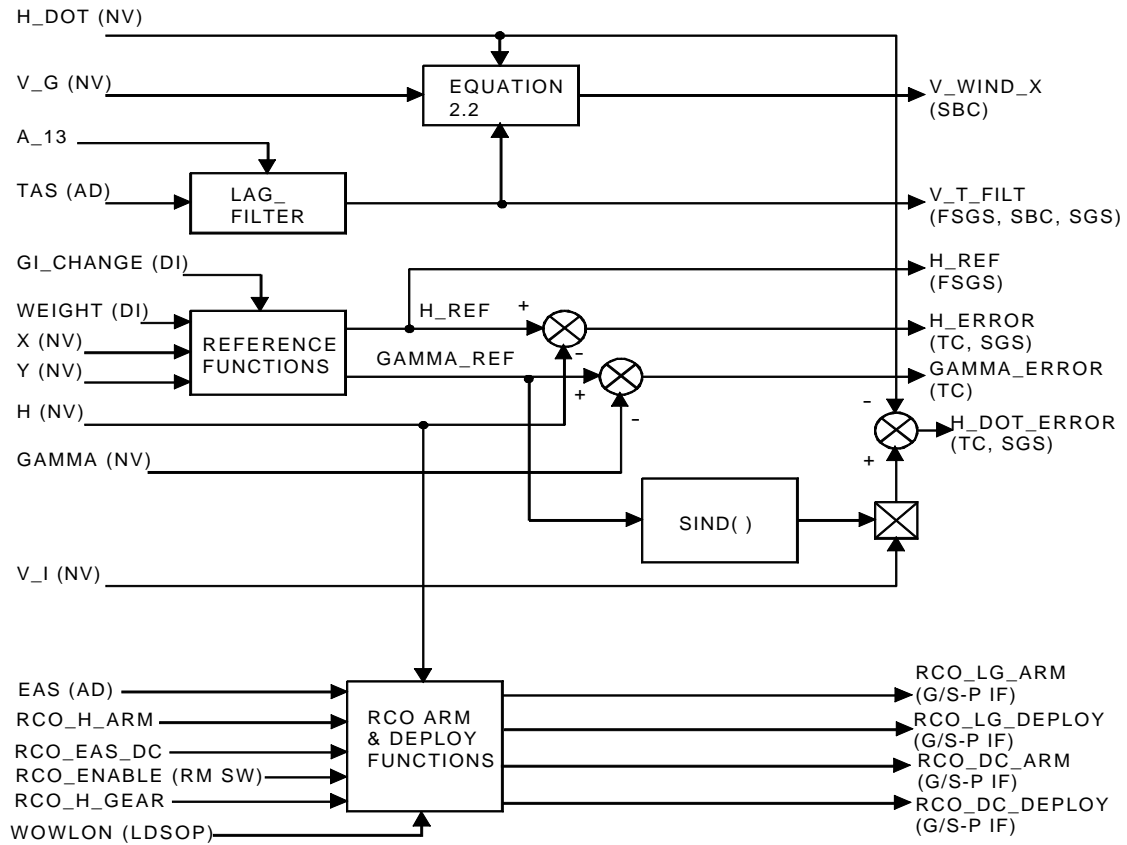


FIGURE 4.7.2.1.1-1. Pitch Trajectory Block Diagram

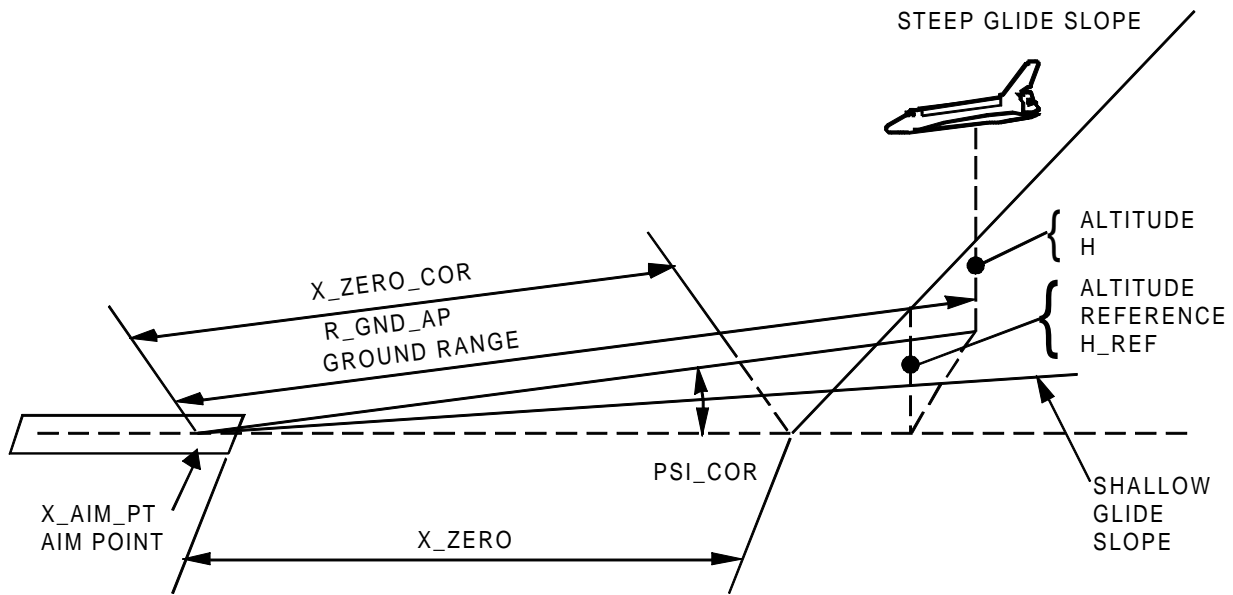


FIGURE 4.7.2.1.1-2. Reference Trajectory Geometry

Table 4.7.2.1.1-1. Pitch Trajectory Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Computation Rate (1/sec)
INPUTS					
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
H_DOT	Estimated altitude rate	NAV	F	ft/sec	6.25
TAS	True airspeed	ADTA SOP	F	ft/sec	1.04
Y	Cross range position WRT RW	NAV	F	ft	6.25
X	Downrange position WRT RW	NAV	F	ft	6.25
GAMMA	Ground relative flight path angle	NAV	F	deg	6.25
V_I	Ground relative velocity magnitude	NAV	F	ft/sec	6.25
V_G	Ground speed	NAV	F	ft/sec	6.25
MASS	Current vehicle mass	DEORB GUID	F	slugs	N/A
GI_CHANGE	Steep glide slope ground intercept redesignation flag	HORIZ SIT DISP	D	ND	6.25
F_MODE	FSGS mode flag	F&SGS	I	ND	6.25
EAS	Equivalent air speed	ADTA SOP	F	ft/sec	1.04
WOWLON	Weight on main wheels	LNDG SOP	D	ND	6.25
RCO_ENABLE	RCO Inhibit/Enable command	RM SWITCH/ SURF FB DISP	D	ND	N/A
OUTPUTS					
V_T_FILT	Filtered true airspeed	F&SGS, SBC, TLM	F	ft/sec	6.25
H_ERROR	Altitude error	TC, SGS, TLM, HUD PROC , HORIZ SIT SPEC, E/L ADI PROC	F	ft	6.25
GAMMA_ERROR	Flight path error	TC, TLM	F	deg	6.25
P_MODE	Pitch subphase mode indicator	LONG. GUID, TLM, HUD PROC	I	ND	6.25
H_REF	Altitude reference	FSGS, TLM	F	ft	6.25
H_DOT_ERROR	Altitude rate error	SGS, TLM	F	ft/sec	6.25
IGS	Steep glide slope index	F&SGS, SBC, HUD PROC, TLM	I	ND	6.25
IGI	Ground intercept index	F&SGS, SBC, HUD PROC	I	ND	6.25

Table 4.7.2.1.1-1. Pitch Trajectory Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Computation Rate (1/sec)
R_GND_AP	Range to runway target	VERT SIT DIP, HORIZ SIT SPEC, TLM	F	ft	6.25
RETRACT_BF	Retract body flap flag	AEROJET DAP	D	ND	6.25
V_WIND_X	Computed wind speed	SBC, TLM	F	ft/sec	6.25
RCO_DC_ARM	RCO drag chute arm command	GNC/SM-PL IF, TLM	D	ND	6.25
RCO_DC_DEPLOY	RCO drag chute deploy command	GNC/SM-PL IF, TLM	D	ND	6.25
RCO_LG_ARM	RCO landing gear arm command	GNC/SM-PL IF, TLM	D	ND	6.25
RCO_LG_DEPLOY	RCO landing gear deploy command	GNC/SM-PL IF TLM	D	ND	6.25

Table 4.7.2.1.1-2. Pitch Trajectory Function I-Loads/Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V97U0002C	A_13	Airspeed filter constant	1.00	F	sec ⁻¹	K
V97U0454C	X_ZERO(I)*	X-intercept of steep glide slope		F	ft	MX
V97U0455C						
V97U0233C	GAMMA_REF_1(I)*	Steep glide slope flight path reference		F	deg	MX
V97U0234C						
V97U0235C	GAMMA_REF_2	Shallow glide slope flight path reference		F	deg	MX
V97U0326C	P_MODE_INITIAL	Initial pitch subphase indicator	1	I	ND	K
V97U0445C	X_AIM_PT	Shallow glide slope X-intercept		F	ft	MX
V97U0444C	WT_GS1	Mass for steep glide slope determination		F	slugs	MX
V97U0492C	INIT_REF_BF	Initial body flap retract command		D	ND	MX
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X
V97U0198C	RCO_H_ARM	Altitude trigger for arming of landing gear during RCO landing		F	ft	SX
V97U3403C	RCO_H_GEAR	Altitude trigger for landing gear deploy during RCO landing		F	ft	SX
V97U3401C	RCO_EAS_DC	Airspeed limit for drag chute arm & deploy during RCO landing		F	ft/sec	SX
*I = 1, 2						

Table 4.7.2.1.1-3. Pitch Trajectory Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Filtered true airspeed	TAEM	First-pass	V_T_FILT	TAS
Retract body flap flag	TAEM	First-pass	RETRACT_BF	INIT_REF_BF
Pitch subphase mode indicator	TAEM	First-pass	P_MODE	P_MODE_INITIAL
Steep glide slope index	TAEM	First-pass	IGS	1, MASS ≤ WT_GS1 2, MASS > WT_GS1
Ground intercept index	TAEM	First-pass	IGI	1, GI_CHANGE = FALSE 2, GI_CHANGE = TRUE

4.7.2.1.2 Trajectory Capture.

Figure 4.7.2.1.2-1 is a block diagram of the Trajectory Capture subfunction. This subfunction is to compute, as an output to the flight control subsystem, a normal acceleration command. Execution of the Trajectory Capture subfunction will result in a feedback guidance command to effect capture of linear steep glide slope trajectory. The feedback law generates a command (NZ_C2H) proportional to the trajectory error and a damping signal (NZ_C1) proportional to the altitude rate error.

A. Detailed Requirements. The Trajectory Capture subfunction in itself will only perform a pitch subphase mode transition test as described immediately below. Command processing will actually avail use of the Steep Glide Slope subfunction.

1. A logic test is first performed for initiation of the next subphase (steep glide slope). The logic for this transition is that the steep glide slope subphase (P_MODE = 2) is initiated if (a) the magnitude of the flight path error GAMMA_ERROR is less than the value of GAMMA_CAPTURE and the magnitude of the altitude error H_ERROR is less than H_ERROR_CAPTURE, or (b) the magnitude of the flight path error, GAMMA_ERROR, is less than GAMMA_CAPTURE for greater than T_Q seconds consecutively.
2. Pitch command processing for the Trajectory Capture subfunction is simply performed via the Steep Glide Slope subfunction as indicated in Equation Set 2. The prime SGS output is the unlimited normal acceleration command (NZ_C) to the command compensator and limiter (Ref 4.7.2.1).
 - 2.1 Execute Steep Glide Slope subfunction (Section 4.7.2.1.3).

B. Interface Requirements. The input/output parameters specifically associated with Trajectory Capture processing are presented in Table 4.7.2.1.2-1. The constants are presented in Table 4.7.2.1.2-2.

C. Processing Requirements. Execution of Trajectory Capture processing follows Pitch Trajectory processing if the subphase mode flag is set to the value for this trajectory interval (P_MODE = 1). The processing must be done during each A/L guidance cycle. The computation cycle that detects a change in P_MODE is the last pass through Trajectory Capture.

D. Initialization Requirements. The initialization requirements for Trajectory Capture subfunction are shown in Table 4.7.2.1.3-3.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

A functional flow for the Approach/Landing Trajectory Capture function is provided in section 5.1.3.

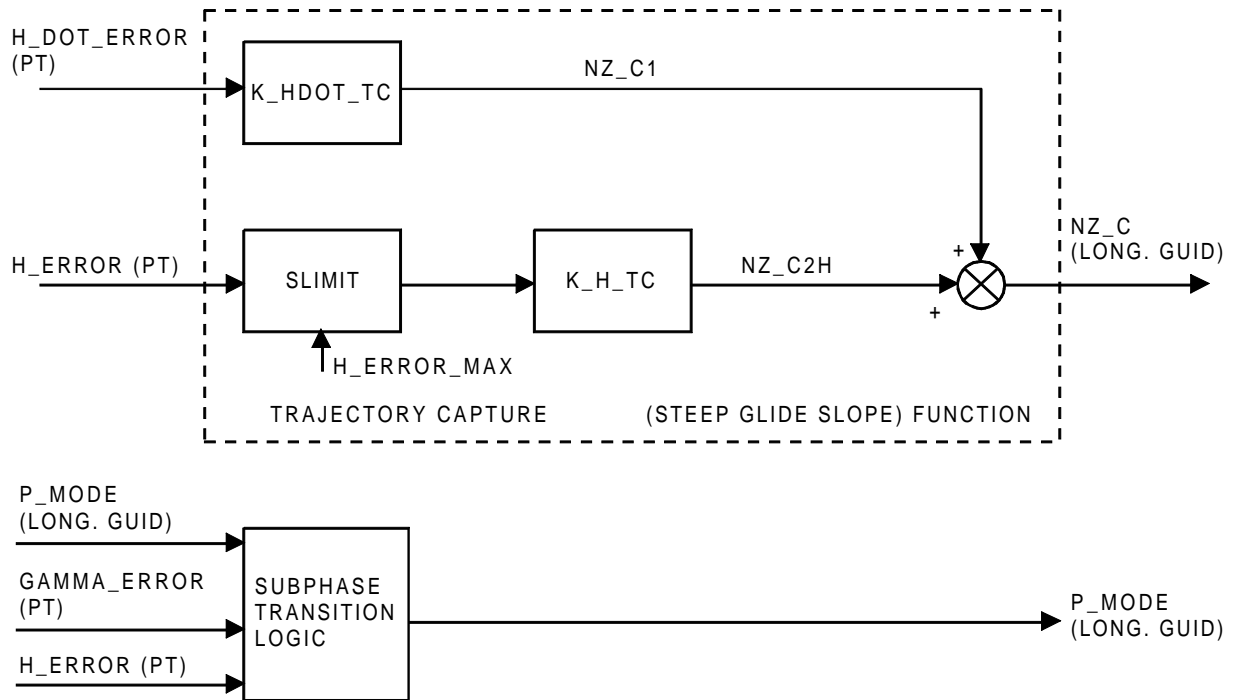


FIGURE 4.7.2.1.2-1. Trajectory Capture Block Diagram

Table 4.7.2.1.2-1. Trajectory Capture Input/Output Parameters					
Name	Description	Source/Destination	Type	Units	Computation Rate (1/sec)
INPUT					
H_ERROR	Altitude error	PT	F	ft	6.25
GAMMA_ERROR	Flight path angle error	PT	F	deg	6.25
P_MODE	Pitch subphase mode indicator	LONG. GUID	I	ND	6.25
OUTPUT					
P_MODE	Pitch subphase mode indicator	LONG. GUID, TLM	I	ND	6.25

Table 4.7.2.1.2-2. Trajectory Capture Function Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V97U0229C	GAMMA_CAPTURE	Maximum gamma error to engage steep glide slope subphase	2.00	F	deg	K
V97U0268C	H_ERROR_CAPTURE	Maximum altitude error to engage steep glide slope subphase	50.0	F	ft	K
V97U0409C	T_Q	Minimum time with bounded error to engage steep glide slope subphase	4.0	F	sec	K
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X

4.7.2.1.3 Steep Glide Slope.

Figure 4.7.2.1.3-1 is the block diagram for the steep glide slope subfunction. This subfunction is to compute as output to the flight control the normal acceleration guidance command (NZC) during both the trajectory capture and steep glide slope subphases.

The steep glide slope subfunction computes normal acceleration commands to acquire and track the steep glide slope trajectory. The normal acceleration command is derived from altitude and altitude rate errors with respect to the steep glide slope reference. During the steep glide slope subphase, an altitude error integral component is also included to minimize stand-off errors. This function also tests for transition to the flare and shallow glide slope subphase (P_MODE = 3).

A. Detailed Requirements. The logical processes in computing the steep glide slope equations are as follows:

1. The variables of Equation Set 1 are initialized on first pass. Equations 1.1, 1.2, and 1.3 are initialized on first pass of the trajectory capture subphase (P_MODE = 1). Equations 1.4, 1.5, and 1.6 are initialized on first-pass of the steep glide slope subphase (P_MODE = 2).
 - 1.1 $K_HINT = 0.$
 - 1.2 $K_C1G = K_H_DOT_TC$
 - 1.3 $K_C2H = K_H_TC$
 - 1.4 $K_HINT = K_HINT1$
 - 1.5 $K_C1G = K_H_DOT_SGS$
 - 1.6 $K_C2H = K_H_SGS$
2. A test for initiation of the flare and shallow glide slope subphase is now made. The test is based on comparing the orbiter altitude (H) with a predetermined altitude (H_FLARE). When the altitude drops below this value, then the pitch subphase mode flag is changed (P_MODE = 3).
3. Components of the normal acceleration guidance command (NZC) are computed in Equation Set 3. The components are the altitude rate error (NZ_C1) component and the altitude error component (NZ_C2).
 - 3.1 $NZ_C1 = K_C1G H_DOT_ERROR$
 - 3.2 $NZ_C2H = K_C2H SLIMIT(H_ERROR, H_ERROR_MAX)$
 - 3.3 $NZ_C2I_DOT = K_HINT SLIMIT(H_ERROR, H_INTMX)$
 - 3.4 $NZ_C2I = INTEGRAL(NZ_C2I_DOT)$
 - 3.5 If (AUTOP_LAMP = OFF), then (NZ_C2I = 0)
 - 3.6 $NZ_C2 = NZ_C2H + NZ_C2I$

4. The unlimited normal acceleration command is computed in Equation Set 4.

$$4.1 \quad NZ_C = NZ_C1 + NZ_C2$$

B. Interface Requirements. The input/output parameters associated with the Steep Glide Slope subfunction are presented in Table 4.7.2.1.3-1. The I-loads are presented in Table 4.7.2.1.3-2.

C. Processing Requirements. Execution of Steep Glide Slope processing follows Pitch Trajectory processing if the subphase mode flag is set to value for this flight phase (P_MODE = 2) or follows Trajectory Capture processing when P_MODE = 1 (including the P_MODE = 1 to 2 transition guidance cycle). The processing must be done once each guidance cycle. The computation cycle that detects a change in P_MODE to the flare and shallow glide slope subphase is the last pass through the Steep Glide Slope subfunction.

D. Initialization Requirements. The initialization requirements for the Steep Glide Slope subfunction are shown in Table 4.7.2.1.3-3.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

A functional flow for the Approach/Landing Steep Glide Slope function is provided in section 5.1.3.

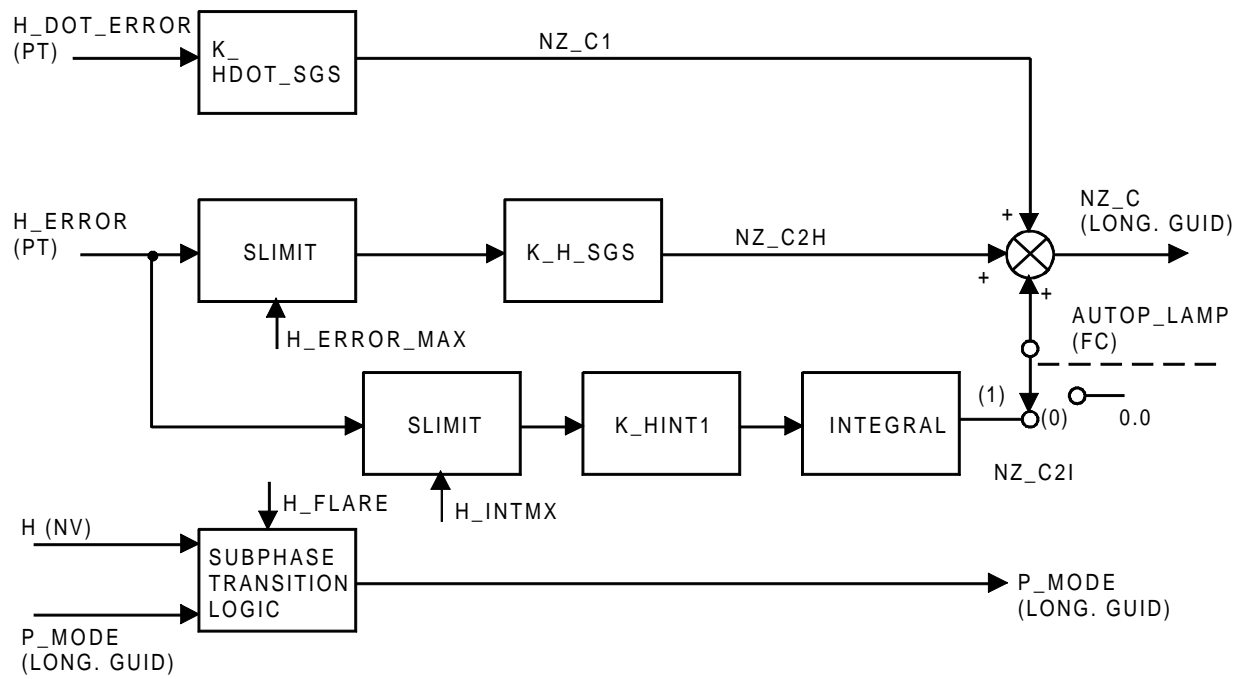


FIGURE 4.7.2.1.3-1. Step Glide Slope Block Diagram

Table 4.7.2.1.3-1. Steep Glide Slope Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/sec)
INPUTS					
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
H_ERROR	Altitude error	PT	F	ft	6.25
H_DOT_ERROR	Altitude rate error	PT	F	ft/sec	6.25
P_MODE	Pitch subphase mode indicator	LONG. GUID	I	ND	6.25
AUTOP_LAMP	Auto lamp status, pitch	AEROJET DAP	D	ND	6.25
OUTPUTS					
P_MODE	Pitch subphase mode indicator	LONG. GUID, TLM	I	ND	6.25
NZ_C	Unlimited normal acceleration command	TLM, LONG. GUID	F	g	6.25
NZ_C1	Normal acceleration command 1	TLM	F	g	6.25
NZ_C2H	Normal acceleration command 2 altitude error component	TLM	F	g	6.25
NZ_C2I	Normal acceleration command 2 integral component	TLM	F	g	6.25

Table 4.7.2.1.3-2. Steep Glide Slope Function I-Loads / Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V97U0269C	H_ERROR_MAX	Maximum altitude error		F	ft	SX
V97U0272C	H_INTMX	Altitude error integrator maximum		F	ft	SX
V97U0307C	K_HINT1	Integrator gain NZ_C2, steep glide slope subphase		F	g/(ft-sec)	SX
V97U0305C	K_HDOT_SGS	Altitude rate error gain, SGS		F	g-sec/ft	SX
V97U0301C	K_H_SGS	Altitude error gain, SGS		F	g/ft	SX
V97U0271C	H_FLARE	Altitude for transition to FSGS (P_MODE = 3)		F	ft	SX
V97U0306C	K_HDOT_TC	Altitude rate error gain, TC		F	g-sec/ft	SX
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X
V97U0302C	K_H_TC	Altitude error gain, TC		F	g/ft	SX

Table 4.7.2.1.3-3. Steep Glide Slope Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Altitude error integrator gain	—	First-pass of SGS function	K_HINT	0
Glide slope error gain	—	First-pass of SGS function	K_C1G	K_HDOT_TC
Altitude error gain	—	First-pass of SGS function	K_C2H	K_H_TC
Altitude error integrator gain	TC phase	SGS phase	K_HINT	K_HINT1
Glide slope error gain	TC phase	SGS phase	K_C1G	K_HDOT_SGS
Altitude error gain	TC phase	SGS phase	K_C2H	K_H_SGS
Integral component of NZ_C2	—	Upon initial A/L guidance execution	NZ_C2I	0

4.7.2.1.4 Flare and Shallow Glide Slope.

The Flare and Shallow Glide Slope subfunction computes feed-forward and feedback guidance commands to track a nominal reference trajectory between the steep and shallow glide slopes (Figure 4.7.2.1.4-1). The feed-forward guidance laws generate normal acceleration commands to follow the nominal trajectory. The feedback guidance laws compensate for errors due to imperfect trajectory and environment-induced errors. Testing for transition to the final flare subphase (P_MODE = 4) is also performed.

Figure 4.7.2.1.4-2 is a block diagram of Flare and Shallow Glide Slope subfunction. This subfunction is to generate normal acceleration commands to the flight control subsystem. In addition, the Flare and Shallow Glide Slope subfunction issues a retract body flap flag (RETRACT_BF) to the flight control subsystem to signal positioning of the body flap at its landing position.

A. Detailed Requirements. The logical processes for computing the equations are as follows:

1. The variables and flags of Equation Set 1 are initialized on the first-pass through the Flare and Shallow Glide Slope subfunction. The subfunction flag (F_MODE) is set to the pull-up initiation value. Three trajectory intervals are determined by the F_MODE flag, viz.

$$F_MODE = \begin{cases} 1, & \text{pullup initiation} \\ 2, & \text{circularization} \\ 3, & \text{exponential capture} \end{cases}$$

The retract body flap flag (RETRACT_BF) is also set to command the flight control subsystem to position the body flap to its landing position (RETRACT_BF = ON).

$$1.1 \quad NZ_C2I = 0.0$$

$$1.2 \quad GAMMA_C3 = 0.0$$

$$1.3 \quad F_MODE = 1$$

$$1.4 \quad RETRACT_BF = ON$$

$$1.5 \quad GAMMA_AIR_SYNC = ARCSIND(H_DOT/V_T_FILT)$$

2. A logical test is made for changing to exponential capture. If (a) the flare and shallow glide slope is operating on the circularization trajectory (F_MODE = 2) and (b) the ground range (X), which is a negative quantity, exceeds the reference range (X_EXP_IGS,IGI), then the flare and shallow glide slope flag is set to exponential capture value (F_MODE = 3). If (a) the flare and shallow glide slope is operating on circularization trajectory and (b) X does not exceed X_EXP_IGS,IGI, then the circularization equations (Set 2) are computed. Included are the reference trajectory variables H_REF_T and H_REF_T_DOT for the altitude and altitude rate, respectively.

$$2.1 \quad H_REF_T = H_K_{IGS,IGI} - \sqrt{(R_{IGS,IGI})^2 - (X - X_{K_{IGS,IGI}})^2}$$

$$2.2 \quad H_REF_T_DOT = -V_G (X - X_{K_{IGS,IGI}})/(H_REF_T - H_{K_{IGS,IGI}})$$

3. A logical test is made for change of subphase to next subphase (final flare). Final flare is initiated ($P_MODE = 4$) if (a) the guidance is operating in the exponential capture mode ($F_MODE = 3$); (b) the altitude, H , is below a predetermined value H_FF ; and (c) the altitude, H , is below the computed altitude H_FINAL_FLARE in Equation 3.1. If the altitude, H , is below a minimum value H_MIN , then the pitch subphase mode flag is set to the final flare value ($P_MODE = 4$).

$$3.1 \quad H_FINAL_FLARE = TAU_TD (H_TD2_DOT - H_DOT) + H_NO_ACC$$

4. If the operating mode is exponential capture ($F_MODE = 3$), then the trajectory reference variables of Equation Set 4 are computed. These include the altitude (H_REF_T) and altitude rate ($H_REF_T_DOT$) variables.

$$4.1 \quad H_ERRORX = H_DECAY \text{ EXP}((X_EXP_{IGS,IGI} - X)/SIGMA_{IGS})$$

$$4.2 \quad H_REF_T = H_REF + H_ERRORX$$

$$4.3 \quad H_REF_T_DOT = V_G (TAND(GAMMA_REF_2) - H_ERRORX/SIGMA_{IGS})$$

5. A logical test is made for changing mode to circularization ($F_MODE = 2$). If (a) the operating mode is pullup initiation ($F_MODE = 1$), and (b) the altitude (H) is below a predetermined value (H_CLOOP), then the mode flag is changed to circularization value ($F_MODE = 2$).

If the operating mode is pullup initiation ($F_MODE = 1$), then the feedback command (NZ_C4) is set to zero in Equation (5.1).

$$5.1 \quad NZ_C4 = 0.0$$

6. If the operating mode flag (F_MODE) is not the pullup initiation value ($F_MODE \neq 1$), then the trajectory error parameters are computed in Equation Set 6. These are the altitude error (H_ERROR) and altitude rate error (H_DOT_ERROR) parameters in Equations 6.1 and 6.2, respectively.

$$6.1 \quad H_ERROR = H_REF_T - H$$

$$6.2 \quad H_DOT_ERROR = H_REF_T_DOT - H_DOT$$

7. If the operating mode flag (F_MODE) is not the pullup initiation value ($F_MODE \neq 1$), then the feedback attitude command (NZ_C4) is computed in Equation Set 7. The integral function component of NZ_C4 (NZ_C2I) is set to zero if the flight control subsystem is operating in manual mode ($AUTOP_LAMP = OFF$); otherwise, the integral function is computed by Equation 7.3.

$$7.1 \quad NZ_C2H = K_H_FSGS H_ERROR$$

$$7.2 \quad NZ_C2I_DOT = K_INT_FSGS NZ_C2H$$

$$7.3 \quad NZ_C2I = INTEGRAL(NZ_C2I_DOT)$$

- 7.4 If (AUTOP_LAMP = OFF), then NZ_C2I = 0.
- 7.5 $NZ_C4 = NZ_C2H + K_HDOT_FSGS H_DOT_ERROR + NZ_C2I$
8. The unlimited normal acceleration command is computed.
- 8.1 $NZC_MAX = V_I^2/R_{IGS,IGI}$
- 8.2 $GAMMA_DOT_MAX = DEG_PER_RAD NZC_MAX/V_T_FILT$
- 8.3 $GAMMA_C3_DOT = SLIMIT((GAMMA_REF_2 - GAMMA_AIR_SYNC - GAMMA_C3)/TAU_GAMMA, GAMMA_DOT_MAX)$
- 8.4 $GAMMA_C3 = INTEGRAL(GAMMA_C3_DOT)$
- 8.5 $NZ_C3 = LAG_FILTER(A_40, V_T_FILT GAMMA_C3_DOT / (DEG_PER_RAD GO))$
- 8.6 $NZ_C = NZ_C3 + NZ_C4$

B. Interface Requirements. The input/output parameters associated with the Flare and Shallow Glide Slope subfunction are presented in Table 4.7.2.1.4-1. I-loads/constants are presented in Table 4.7.2.1.4-2.

C. Processing Requirements. Execution of Flare and Shallow Glide Slope processing follows Pitch Trajectory processing if the subphase mode flag is set to the value for this flight phase (P_MODE = 3). The processing must be done once each guidance cycle. The computation cycle that detects a change in P_MODE is the last pass through the Flare and Shallow Glide Slope subfunction.

D. Initialization Requirements. The initialization requirements for the Flare and Shallow Glide Slope subfunction are shown in Table 4.7.2.1.4-3.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

A functional flow for the Approach/Landing Flare and Shallow Glide Slope function is provided in section 5.1.3.

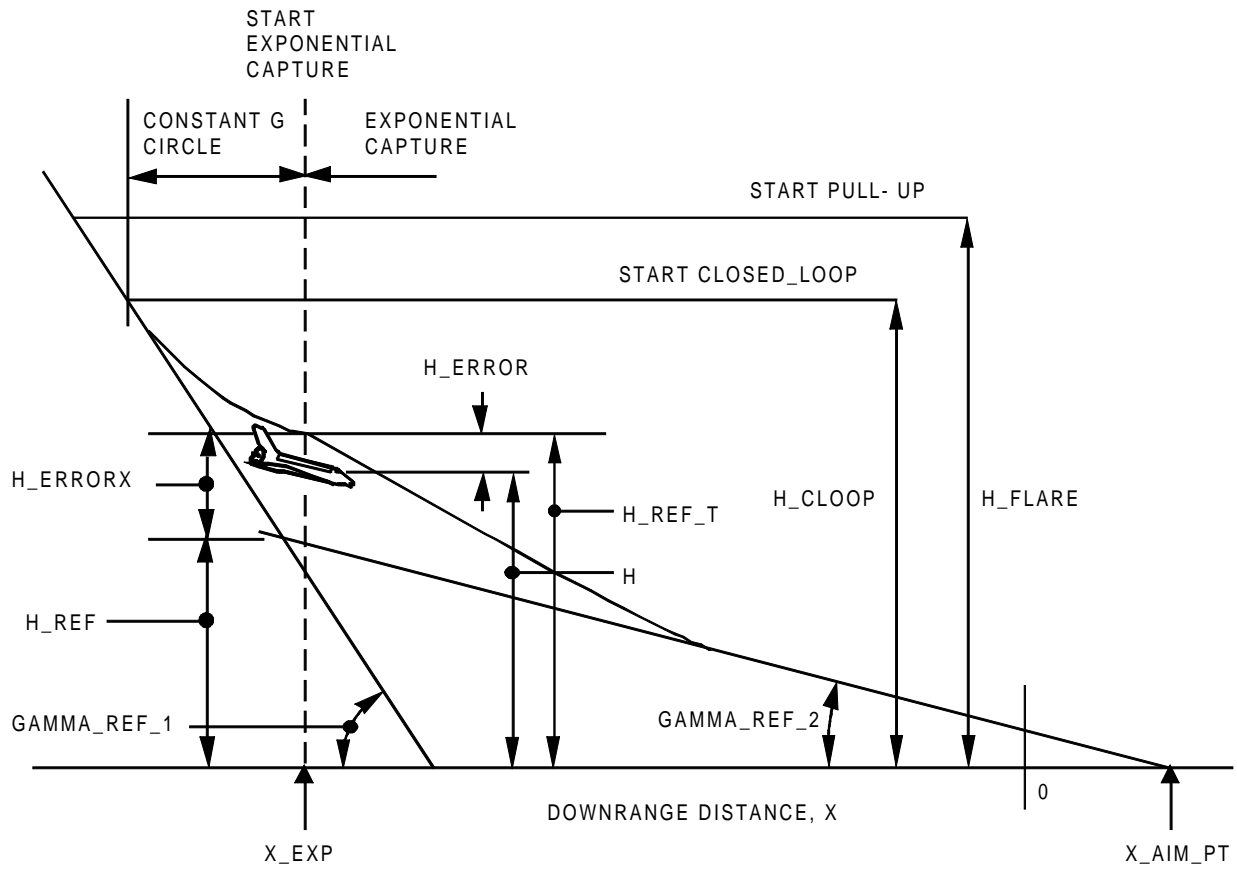


FIGURE 4.7.2.1.4-1. Flare and Shallow Glide Slope Trajectory

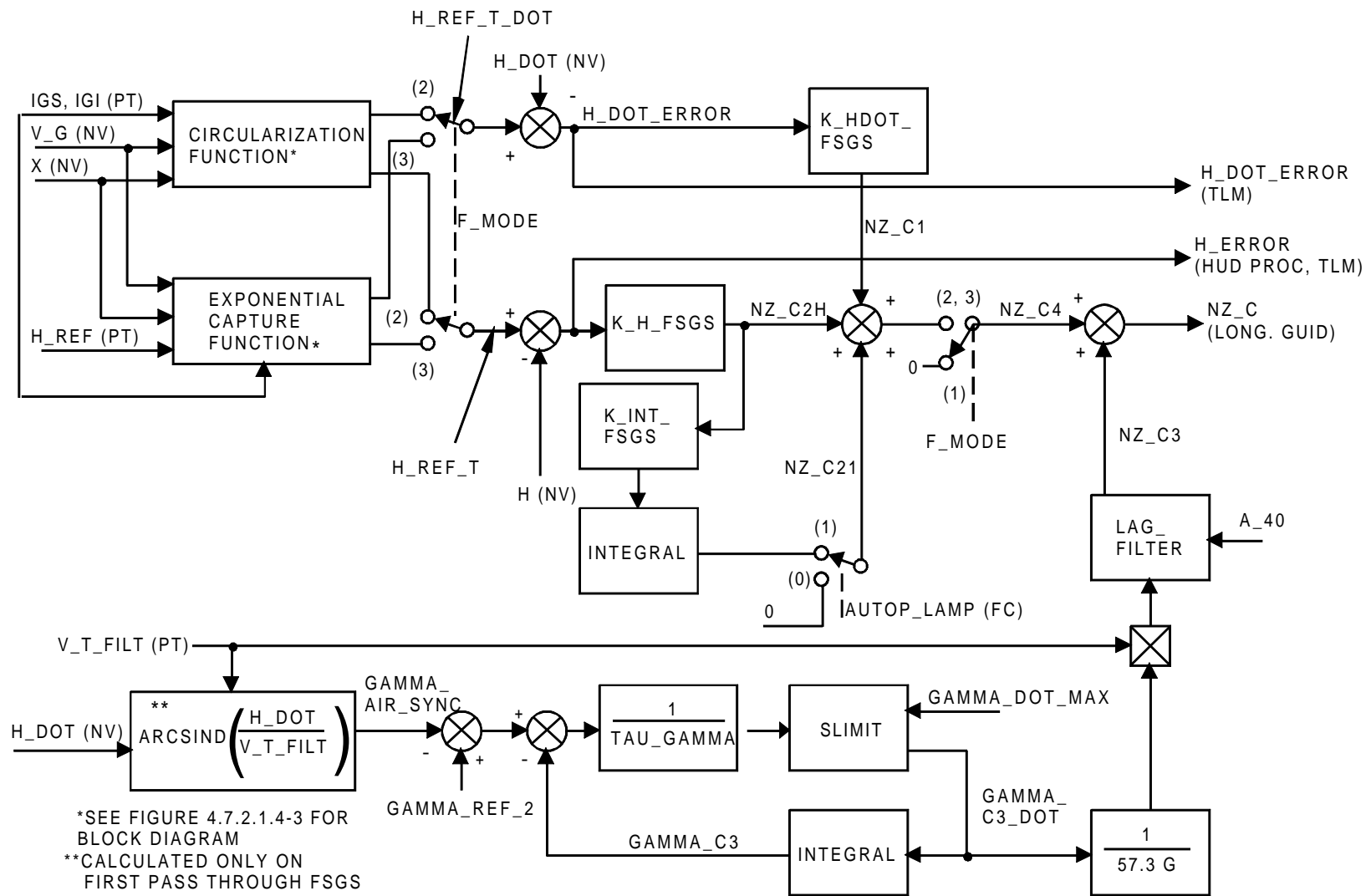


FIGURE 4.7.2.1.4-2. Flare and Shallow Glide Slope Block Diagram.

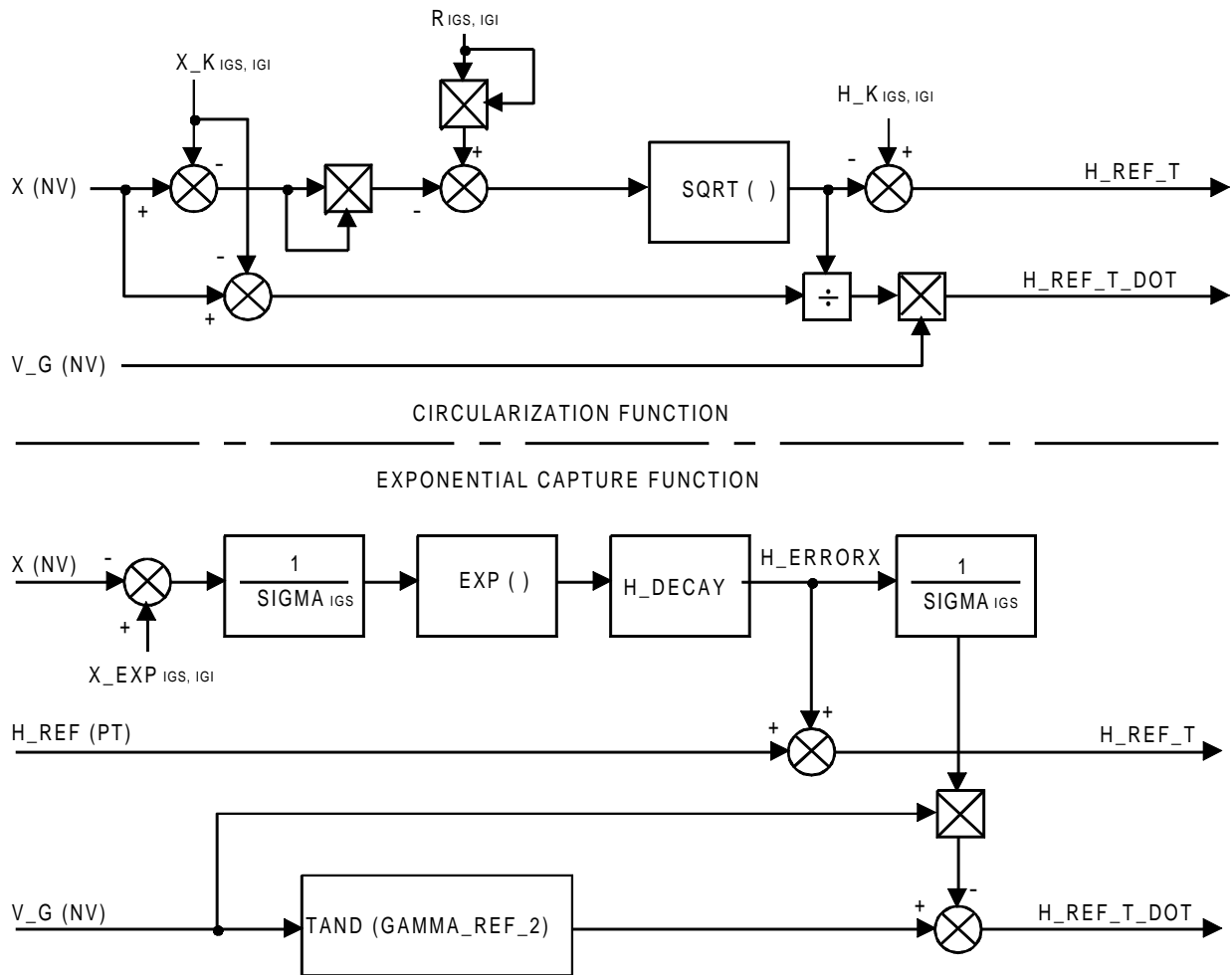


FIGURE 4.7.2.1.4-3. Circularization and Exponential Capture Functional Block Diagram

Table 4.7.2.1.4-1. Flare and Shallow Glide Slope Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/sec)
INPUTS					
V_G	Projected ground relative velocity magnitude	NAV	F	ft/sec	6.25
X	Downrange position WRT RW	NAV	F	ft	6.25
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
V_I	Ground relative velocity magnitude	NAV	F	ft/sec	6.25
AUTOP_LAMP	Auto lamp status, pitch axis	AEROJET DAP	D	ND	6.25
H_DOT	Estimated altitude rate	NAV	F	ft/sec	6.25
H_REF	Altitude reference	PT	F	ft	6.25
V_T FILT	Filtered airspeed	PT	F	ft/sec	6.25
IGS	Steep glide slope index	PT	I	ND	6.25
IGI	Steep glide slope ground intercept index	PT	I	ND	6.25
OUTPUTS					
RETRACT_BF	Retract body flap flag	AEROJET DAP	D	ND	6.25
P_MODE	Pitch subphase mode indicator	LONG. GUID	I	ND	6.25
F_MODE	FSGS mode flag	TLM, PT	I	ND	6.25
GAMMA_C3	Flight path command	TLM	F	deg	6.25
GAMMA_C3_DOT	Flight path command rate	TLM	F	deg/sec	6.25
H_REF_T	Altitude reference	TLM	F	ft	6.25
H_REF_T_DOT	Altitude rate reference	TLM	F	ft/sec	6.25
NZ_C	Unlimited normal acceleration command	TLM, LONG. GUID, FF	F	g	6.25
NZ_C2I	Unlimited NZ command 2 integral component	TLM	F	g	6.25
NZ_C2H	Normal acceleration command 2 altitude error component	TLM	F	g	6.25
NZ_C3	Normal acceleration command 3	TLM	F	g	6.25
NZ_C4	Normal acceleration command 4	TLM	F	g	6.25
H_ERROR	Altitude error	TLM, HUD PROC	F	ft	6.25
H_DOT_ERROR	Altitude rate error	TLM	F	ft/sec	6.25

Table 4.7.2.1.4-2. Flare and Shallow Glide Slope Function I-Loads/Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V97U0446C V97U0447C V97U0448C V97U0449C	X_EXP(I,J)**	X to start exponential capture		F	ft	MX
V97U0273C V97U0274C V97U0275C V97U0276C	H_K(I,J)**	Constant G–circle center altitude		F	ft	MX
V97U0379C V97U0380C V97U0381C V97U0382C	R(I,J)**	Constant G–circle radius		F	ft	MX
V97U0450C V97U0451C V97U0452C V97U0453C	X_K(I,J)**	Constant G–circle center		F	ft	MX
V97U0270C	H_FF	Altitude to start checking final flare altitude		F	ft	SX
V97U0411C	TAU_TD	Time constant final flare altitude equation		F	sec	SX
V97U0285C	H_TD2_DOT	Closed–loop touchdown altitude rate		F	ft/sec	SX
V97U0278C	H_NO_ACC	Altitude for zero acceleration		F	ft	SX
V97U0402C V97U0403C	SIGMA(I)*	Exponential distance		F	ft	MX
V97U0235C	GAMMA_REF_2	Shallow guide slope flight path angle reference		F	deg	MX
V97U0266C	H_DECAY	Exponential capture altitude reference		F	ft	MX
V97U0265C	H_CLOOP	Altitude to initiate closed–loop pullup		F	ft	MX
V97U0309C	K_INT_FSGS	Integrator gain		F	sec ⁻¹	SX
V97U0410C	TAU_GAMMA	Time constant, GAMMA_C3		F	sec	SX
V97U0112C	DEG_PER_RAD	Radian–to–degree conversion factor	57.2957795131	F	deg/rad	X
V97U0277C	H_MIN	Minimum altitude for final flare		F	ft	SX
V90A7622C	GO	Earth gravitational constant	32.174049	F	ft/sec ²	X
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X
V97U0300C	K_H_FSGS	Altitude error gain		F	g/ft	SX
V97U0304C	K_HDOT_FSGS	Altitude rate error gain		F	g–sec/ft	SX
V97U0005C	A_40	Open–loop filter constant		F	sec ⁻¹	SX
*I = 1, 2 **I = 1, 2; J = 1, 2						

Table 4.7.2.1.4-3. Flare and Shallow Glide Slope Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Integral component of NZ_C2	—	First-pass	NZ_C2I	0
Retract body flap flag	—	First-pass	RETRACT_BF	ON
FSGS mode indicator	—	First-pass	F_MODE	1
Flight path angle command	—	First-pass	GAMMA_C3	0
Flight path angle air mass sync	—	First-pass	GAMMA_AIR_SYNC	ARCSIN(H_DOT/ V_T_FILT) DEG_PER_RAD

4.7.2.1.5 Final Flare.

The Final Flare subfunction computes open-loop and feedback normal acceleration commands to achieve an exponential flare trajectory (Figure 4.7.2.1.5-1). The open-loop feed-forward laws generate the normal acceleration command required to achieve the desired vertical deceleration.

The reference altitude rate (H_REF_DOT) is computed as a linear function of landing gear height above the runway plane and an error parameter formed by using the estimate of altitude rate from the navigation subsystem. The linear perturbation controller generates a normal acceleration command proportional to the filtered altitude-rate error (corrected for the desired bias vertical velocity at touchdown).

A. Detailed Requirements. The logical processes of computing the equations are as follows:

1. The variables of Equation Set 1 are initialized on first pass through final flare.
 - 1.1 $H_REF_DOT = H_DOT$
 - 1.2 $H_DOT_C3 = H_DOT$
 - 1.3 $NZ_C1I = 0.0$
 - 1.4 $H_DOT_SYN = NZ_C/K_HDOT_FF$
2. If the weight-on-rear-wheels event has occurred ($WOWLON = ON$), then the output to the flight control subsystem is set to zero as in Equation Set 2.
 - 2.1 $NZC = 0.0$ (Refer to Supplemental Information)
3. If the weight-on-rear-wheels event has not occurred ($WOWLON = OFF$), then the feed-forward command, NZ_C3 , in Equation Set 3 is computed.
 - 3.1 $H_DDOT_C3 = (H_TD1_DOT + H_DOT_SYN - H_DOT_C3)/TAU_TD1$
 - 3.2 $H_DOT_C3 = INTEGRAL(H_DDOT_C3)$
 - 3.3 $NZ_C3 = K_FLR H_DDOT_C3$
4. If weight-on-rear-wheels event has not occurred ($WOWLON = OFF$), then the altitude rate reference (H_REF_DOT) is computed in Equation Set 4.
 - 4.1 $H_D = H - H_NO_ACC$
 - 4.2 If ($H_D < 0.0$), then ($H_D = 0.0$)
 - 4.3 $H_REF_UF_DOT = H_TD2_DOT - H_D/TAU_TD2$
 - 4.4 $H_REF_DOT = LAG_FILTER(A_3, H_REF_UF_DOT)$

5. If weight-on-rear-wheels event has not occurred, then the unlimited normal acceleration command is computed in Equation Set 5.

$$5.1 \quad NZ_C1H = K_HDOT_FF (H_REF_DOT - H_DOT)$$

$$5.2 \quad NZ_C1I = K_IFLR \text{ INTEGRAL}(NZ_C1H)$$

$$5.3 \quad NZ_C1 = NZ_C1H + NZ_C1I$$

$$5.4 \quad NZ_C = NZ_C1 + NZ_C3$$

B. Interface Requirements. The input/output parameters associated with final flare are presented in Table 4.7.2.1.5-1. The I-loads/constants are presented in Table 4.7.2.1.5-2.

C. Processing Requirements. Execution of final flare processing follows the flare and shallow glide slope flight phase processing, if the subphase mode flag is set to the value appropriate to this flight phase (P_MODE = 4). The processing must continue once each guidance cycle. The computation cycle that detects the touchdown event is the last pass through final flare.

D. Initialization Requirements. The initialization requirements for final flare subfunction are shown in Table 4.7.2.1.5-3.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

The requirement to set the Nz command output to zero upon detection of the weight-on-wheels event is truly meaningless. A review of the Longitudinal Guidance processing requirements (ref: 4.7.2.1) will quickly expose that the Nz command transport lag compensator will simply overwrite this Final Flare, weight-on-wheels, zero value for NZC with the last computed value for NZ_C (albeit the NZ_C value will continue to be limited by the NZC_LIM command magnitude constraint). As described in Section E of Longitudinal Guidance, the impact of this “rewrite” is moot as the FCS no longer “reads” any descent Nz command output once it detects that weight-on-wheels has occurred. Telemetry data may be easily used to verify the foregoing A/L guidance Nz command characteristic.

A functional flow for the Approach/Landing Final Flare function is provided in section 5.1.3.

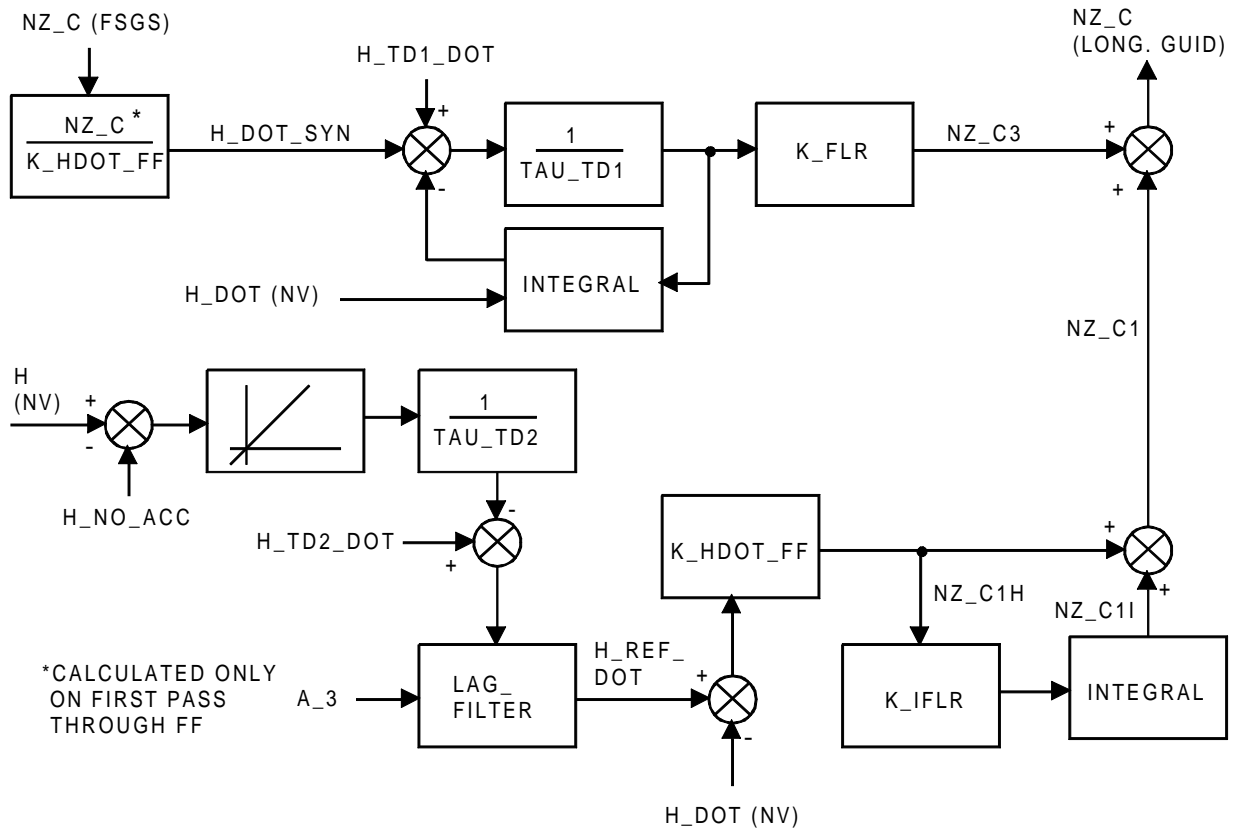


FIGURE 4.7.2.1.5-1. Final Flare Block Diagram

Table 4.7.2.1.5-1. Final Flare Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/sec)
INPUTS					
H_DOT	Estimated altitude rate	NAV	F	ft/sec	6.25
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
WOWLON	Weight on main wheels indicator	LNDG SOP	D	ND	6.25
NZ_C	Unlimited normal acceleration command	FSGS	F	g	6.25
OUTPUTS					
NZ_C	Unlimited normal acceleration command	LONG. GUID. TLM	F	g	6.25
NZ_C1H	Normal acceleration command 1 altitude error component	TLM	F	g	6.25
NZ_C1I	Normal acceleration command 1 integral component	TLM	F	g	6.25
NZ_C1	Normal acceleration command 1	TLM	F	g	6.25
H_REF_DOT	Altitude rate reference	TLM	F	ft/sec	6.25
NZ_C3	Normal acceleration command 3	TLM	F	g	6.25

Table 4.7.2.1.5-2. Final Flare Function I-Loads/Constants						
MSID No.	Name	Description	Type	Value	Units	Class
V97U0413C	TAU_TD2	Time constant final flare altitude equation	F		sec	SX
V97U0412C	TAU_TD1	Time constant, NZ_C3	F		sec	SX
V97U0299C	K_FLR	Gain, NZ_C3 final flare	F		g-sec ² /ft	SX
V97U0004C	A_3	Final flare filter constant	F	10.0	sec ⁻¹	K
V97U0303C	K_HDOT_FF	Gain H_DOT, final flare	F		g-sec/ft	SX
V97U0308C	K_IFLR	Integral gain, H_DOT	F		sec ⁻¹	SX
V97U0284C	H_TD1_DOT	Touchdown altitude rate reference 1	F		ft/sec	SX
V97U0285C	H_TD2_DOT	Touchdown altitude rate reference 2	F		ft/sec	SX
V97U0278C	H_NO_ACC	Altitude for zero acceleration	F		ft	SX
V97U6115C	DT	A/L guidance sample time interval	F	0.16	sec	X
V97U0112C	DEG_PER_RAD	Radian-to-degree conversion factor	F	57.2957795131	deg/rad	X

Table 4.7.2.1.5-3. Final Flare Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Altitude rate reference	—	First-pass	H_REF_DOT	H_DOT
Altitude rate, NZ_C3	—	First-pass	H_DOT_C3	H_DOT
Integral component, NZ_C1	—	First-pass	NZ_C1I	0.0
Altitude rate synchronization	—	First-pass	H_DOT_SYN	NZ_C/K_HDOT_FF

4.7.2.1.6 Speed Brake Command.

The Speed Brake Command subfunction computes the speed brake position (DSBC_AL) and the heads up display (HUD) speed brake retract indicator (HUD_SB_RETRACT) required to maintain the reference equivalent airspeed (Figure 4.7.2.1.6-1). An error parameter (V_ERROR) is formed from the reference equivalent airspeed (V_REF) and the filtered equivalent airspeed (EAS_FILT). A linear perturbation controller generates a desired speed brake position that is proportional to the error parameter, and the integral of the error parameter.

The reference equivalent airspeed is constant for the trajectory capture and steep glide slope subphases but is dependent on the steep glide slope index, IGS. Explicit airspeed control is only mechanized when $H \geq H_SBR_TABLE(1)$. The speed brake is retracted and the HUD speed brake retract indicator is set to TRUE whenever $H < H_SBR_TABLE(1)$.

The speed brake retract angles are determined based on the projected versus desired landing energy state as derived from the estimated winds, velocity error, density altitude, vehicle weight, and whether or not the high wind aim point has been selected by the crew. Additionally, energy compensation for short field landing conditions is provided for whenever the short field option has been set to a non-zero value. The wind and density altitude speed brake retract elements are computed at each retract altitude point to best estimate their effects on touchdown.

An index parameter, SB_MODE, is used to indicate the current operating mode for the speed brake. Speed brake control to achieve and maintain the steep glide slope reference equivalent airspeed is in effect when $SB_MODE = 1$. When $SB_MODE > 1$, a speed brake retract command has been processed. A computed retract angle command will be maintained unless reset by a subsequent retract angle computation ($SB_MODE = SB_MODE + 1$). Regardless of the value for SB_MODE, once weight-on-wheels is indicated ($WOWLON = TRUE$) the speed brake command is set to the touchdown and roll-out desired value (DSBC_WW).

A. Detailed Requirements. The logical processes of computing the equations are as follows:

1. Equation Set 1.1 defines initialization requirements for the Speed Brake Command subfunction. These initialization specifications are to be satisfied prior to all other speed brake processing requirements as defined in subsequent paragraphs or equation sets. Those initialization requirements, dependent on dynamic source parameters or crew inputs, must be performed on first pass execution using the appropriate current source inputs.

Equation Set 1.2 defines processing requirements necessary to be performed on every guidance cycle, independent of altitude and pitch subphase, and as long as the weight on main landing gear event ($WOWLON = ON$) has not occurred.

- 1.1.1 $EAS_FILT = EAS$
- 1.1.2 $V_WIND_FILT = V_WIND_X$
- 1.1.3 $DELTA_SBI = 0.$
- 1.1.4 $DELTA_TI = 0.0001$
- 1.1.5 $V_WIND_INT = 0$

- 1.1.6 HUD_SB_RETRACT = OFF
- 1.1.7 SB_LIM = SB_MAX
- 1.1.8 DSBC_AL = SB_REF
- 1.1.9 SB_MODE = 1
- 1.1.10 $V_ERR_FILT = EAS - V_REF_{IGS}$
- 1.1.11 DR_CI_XO = 0.
- 1.1.12 If IGI = 2, then $DR_CI_XO = X_ZERO(1) - X_ZERO(2)$
- 1.1.13 DR_SRW = 0.
- 1.1.14 If I_SHORT_RW = 1, then $DR_SRW = K_DR_SRW(1)$
- 1.1.15 If I_SHORT_RW = 2, then $DR_SRW = K_DR_SRW(2)$

The equivalent airspeed and the computed wind speed are smoothed every execution cycle as shown in Equation Set 1.2.

- 1.2.1 $EAS_FILT = LAG_FILTER(A_{14}, EAS)$
- 1.2.2 $V_WIND_FILT = LAG_FILTER(A_VWF, V_WIND_X)$

- 2. If the speed brake indicator (SB_MODE) has the value for explicit velocity control (SB_MODE = 1), the speed brake command (DSBC_AL) is computed using Equation Set 2.

- 2.1 $V_ERROR = EAS_FILT - V_REF_{IGS}$
- 2.2 $V_ERR_FILT = LAG_FILTER(A_VWF, V_ERROR)$
- 2.3 $DELTA_SBE = K_SB V_ERROR$
- 2.4 $DEL_INT = K_SBI SLIMIT(V_ERROR, V_LIMIT)$
- 2.5 If $(DSBC_AL \geq SB_MAX$ or $DSBC_AL \leq 0$ or $P_MODE = 1)$, then $(DEL_INT = 0)$
- 2.6 $DELTA_SBI = INTEGRAL(DEL_INT)$
- 2.7 $DSBC_AL = DELTA_SBE + DELTA_SBI + SB_REF$

- 3. Whenever the altitude first becomes less than the altitude to cease explicit velocity control and initiate processing for the speed brake retraction logic ($H < H_SBR_TABLE(1)$ and $SB_MODE = 1$), the HUD speed brake retract flag, HUD_SB_RETRACT, is set to TRUE, the required initialization for the retraction logic is performed and the initial maximum allowable speedbrake retract value is specified using Equation Set 3.

- 3.1 HUD_SB_RETRACT = ON

$$3.2 \quad DR_WT = A_DR_WT_{IGS} + B_DR_WT_{IGS} \text{ LN}(WEIGHT)$$

$$3.3 \quad DR_V_ERROR = S_DR_VEL \text{ V_ERR_FILT}$$

$$3.4 \quad SB_LIM = SB_MAX_RET$$

4. While the altitude is greater than or equal to the second altitude retract point and subsequent to the initial speed brake retract determination ($H \geq H_SBR_TABLE(2)$ and $SB_MODE = 2$), the filtered wind speed and time increment are computed as shown in Equation Set 4.

$$4.1 \quad V_WIND_INT = \text{INTEGRAL}(V_WIND_FILT)$$

$$4.2 \quad DELTA_TI = DELTA_TI + DT$$

5. Whenever the altitude first becomes less than the second speed brake retract altitude (e.g., $H < H_SBR_TABLE(2)$ and $SB_MODE = 2$), the average wind speed is computed and a check is made for final determination of the maximum allowed speed brake retract value for touchdown as shown in Equation Set 5.

$$5.1 \quad V_WIND_FILT = V_WIND_INT/DELTA_TI$$

$$5.2.1 \quad \text{If } I_SHORT_RW = 0, \text{ then } SB_LIM = SB_MAX_TD(1)$$

$$5.2.2 \quad \text{If } I_SHORT_RW > 0, \text{ then } SB_LIM = SB_MAX_TD(2)$$

6. The determination of the desired speed brake retract positioning is made given completion of the appropriate initialization requirements as described previously (Equation Set 3 or 5). The computational process for determining the retract position is to be performed only on that guidance cycle when the altitude first becomes less than the values specified by the speed brake retract altitude table (H_SBR_TABLE). Hence, if ($H < H_SBR_TABLE(1)$ and $SB_MODE = 1$) or if ($H < H_SBR_TABLE(2)$ and $SB_MODE = 2$), then the speed brake command ($DSBC_AL$) for retraction is computed using Equation Set 6.

$$6.1 \quad D_H = S_DH (EAS_FILT/V_T_FILT)**2 \\ + K_DH - H_SBR_TABLE(SB_MODE)$$

$$6.2 \quad DR_DH = S_DR_DH \text{ D_H} + K_DR_DH$$

$$6.3 \quad DR_WIND = S_DR_WIND \text{ V_WIND_FILT}$$

$$6.4 \quad DR_TOTAL = DR_WT + DR_V_ERROR + DR_DH + DR_WIND \\ + DR_CI_XO + DR_SRW$$

$$6.5 \quad DSBC_AL = \text{ALIMIT}(S_SB_DR_{IGS} \text{ DR_TOTAL} + K_SB_DR, 0., SB_LIM)$$

$$6.6 \quad SB_MODE = SB_MODE + 1$$

The above determined speed brake command for retraction will then be maintained (held constant) until either a subsequent command for retraction is processed (i.e., $SB_MODE = SB_MODE + 1$) or until the weight-on-wheels event occurs ($WOWLON = TRUE$).

7. If the weight-on-main-wheels event has occurred ($WOWLON = TRUE$), then the speed brake command to the FCS, $DSBC_AL$, is set to a predetermined value, $DSBC_WW$, as shown in Equation Set 7.
 - 7.1 If $WOWLON = ON$, then $DSBC_AL = DSBC_WW$
8. Finally, after the appropriate speed brake logic has been executed, the speed brake command is limited to be between zero and SB_MAX degrees ($DSBC_AL = ALIMIT(DSBC_AL, 0.0, SB_MAX)$).

B. Interface Requirements. The input/output parameters associated with speed brake command processing are presented in Table 4.7.2.1.6-1. I-loads/ constants are presented in Table 4.7.2.1.6-2.

C. Processing Requirements. Execution of the speed brake command function is made every guidance cycle of the A/L major mode subsequent to processing of the pitch trajectory subfunction.

D. Initialization Requirements. The initialization requirements for the speed brake command subfunction are shown in Table 4.7.2.1.6-3 as shown in Equation Set 1.1 of the speed brake command detailed requirements.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definitions.

The short runway selection option (I_SHORT_RW), as output from displays, will be configured such that upon transition to all descent configurations (OPS6 and OPS3), it will be initialized to 0. Any change to the above default values requires crew intervention subsequent to the OPS3 or 6 transitions and must be made prior to the initiation of APPROACH/LAND to be effective.

A functional flow for the Approach/Landing Speed Brake Command function is provided in section 5.1.3.

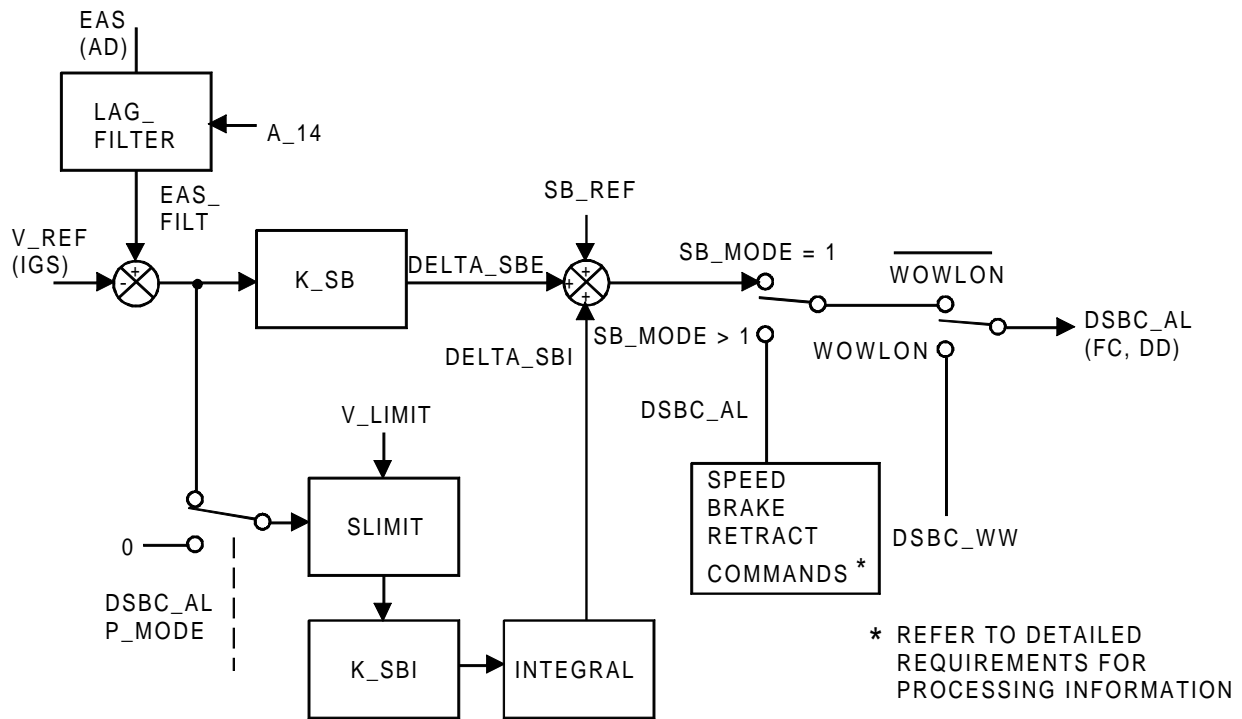


FIGURE 4.7.2.1.6-1. Speed Brake Command Subfunction Block Diagram

Table 4.7.2.1.6-1. Speed Brake Command Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/sec)
INPUTS					
EAS	Equivalent air speed	ADTA SOP	F	ft/sec	1.04
IGS	Steep glide slope index	PT	I	ND	N/A
WOWLON	Weight on main wheels	LNDG SOP	D	ND	6.25
I_SHORT_RW	Short runway selection option	HORIZ SIT DISP	I	ND	6.25
WEIGHT	Vehicle mass	DEORB GUID	F	slugs	N/A
V_WIND_X	Computed windspeed	PT	F	ft/sec	6.25
IGI	Steep glideslope ground intercept index	PT	I	ND	N/A
V_T_FILT	Filtered true air speed	PT	F	ft/sec	6.25
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
P_MODE	Pitch subphase mode indicator	LONG. GUID	I	ND	6.25
OUTPUTS					
DSBC_AL	Speed brake angle command	AEROJET DAP, SPI PROC, VERT SIT DIP, TLM	F	deg	6.25
V_ERROR	Velocity error	TLM	F	ft/sec	6.25
DELTA_SBE	Speed brake command error component	TLM	F	deg	6.25
DELTA_SBI	Speed brake command integral component	TLM	F	deg	6.25
EAS_FILT	Filtered equivalent air speed	TLM	F	ft/sec	6.25
HUD_SB_RETRACT	HUD speed brake retract indicator	HUD	D	ND	6.25
DR_TOTAL	Projected energy range delta at touchdown	TLM	F	ft	6.25
V_WIND_FILT	Filtered windspeed	TLM	F	ft	6.25

Table 4.7.2.1.6-2. Speed Brake Command Function I-Loads/Constants

MSID No.	Name	Description	Value	Type	Units	Class
V97U0003C	A_14	Speed control filter constant	1.00	F	sec ⁻¹	K
V97U0418C	V_REF(I)*	Reference airspeed		F	ft/sec	MX
V97U0419C						
V97U0312C	K_SB	Speed brake control gain		F	deg-sec/ft	SX
V97U0313C	K_SBI	Speed brake control integral to displacement ratio		F	deg/ft	SX
V97U4145C	SB_MAX	Maximum speed brake deflection	98.6	F	deg	K
V97U0397C	SB_REF	Reference speed brake		F	deg	SX
V96U9365C	DSBC_WW	Weight-on-wheels speed brake command		F	deg	SX
V97U0281C	H_SBR_TABLE(I)	Table of altitudes to retract the speed brake		F	ft	SX
V97U0282C	*			(array)		
V97U0417C	V_LIMIT	Maximum error for velocity integrand	10.0	F	ft/sec	K
V97U0454C	X_ZERO(I)*	X-intercept of steep glideslope		F	ft	MX
V97U0455C				(array)		
V99U8820C	A_VWF	Windspeed filter constant		F	sec ⁻¹	MX
V99U8830C	A_DR_WT(I)*	Downrange weight constant		F	ft	MX
V99U8831C				(array)		
V99U8832C	B_DR_WT(I)*	Downrange weight slope		F	ft	MX
V99U8833C						
V99U8822C	K_DH	Density altitude constant		F	ft	MX
V99U8823C	K_DR_DH	Downrange density altitude constant		F	ft	MX
V97U1293C	K_DR_SRW(I)*	Downrange short runway constant		F	ft	MX
V97U1294C				(array)		
V99U8828C	K_SB_DR	Speed brake downrange constant		F	deg	MX
V99U8829C	S_DR_DH	Downrange density altitude		F	ft/ft	MX
V99U8824C	S_DH	Density altitude slope		F	ft	MX
V99U8826C	S_DR_WIND	Downrange windslope		F	ft-sec/ft	MX
V99U8825C	S_DR_VEL	Downrange velocity slope		F	ft-sec/ft	MX
V99U8834C	S_SB_DR(I)*	Speed brake downrange slope		F	deg/ft	MX
V99U8835C				(array)		
V97U1295C	SB_MAX_RET	Maximum retract SBCMD		F	deg	MX
V97U1296C	SB_MAX_TD(I)*	Maximum touchdown SBCMD		F	deg	MX
V97U1297C				(array)		
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X

*(I = 1, 2)

Table 4.7.2.1.6-3. Speed Brake Command Initialization Requirements

Component	Initialize on Transition		Variable	Initial Value
	From	To		
Speed brake command integral component	—	First-pass	DELTA_SBI	0
Filtered equivalent airspeed	—	First-pass	EAS_FILT	EAS
Speed brake command	—	First-pass	DSBC_AL	SB_REF
HUD speed brake retract indicator	—	First-pass	HUD_SB_RETRACT	FALSE
Filtered windspeed	—	First-pass	V_WIND_FILT	V_WIND_X
Time integral	—	First-pass	DELTA_TI	0.0001
Wind speed integral	—	First-pass	V_WIND_INT	0
Speed brake mode indicator	—	First-pass	SB_MODE	1
Downrange delta for close-in X_ZERO	—	First-pass	DR_CI_XO	*
Downrange delta for short runway option	—	First-pass	DR_SRW	*
Filtered velocity error	—	First-pass	V_ERR_FILT	*
Maximum allowed speed brake retract command	—	First-pass	SB_LIM	SB_MAX

*See Equation Set 1.1.

4.7.2.2 Lateral Guidance.

Lateral guidance provides roll attitude commands to the flight control and to displays throughout the A/L major mode. Yaw rate commands are computed as output to the flight control subsystem after flat turn initiation through touchdown and rollout. The formulation of lateral guidance is defined by the Roll Command subfunction and the Touchdown and Roll-out subfunction.

A. Detailed Requirements. The logical process of computing the lateral guidance subfunctions is shown in Equation Set 1 as is depicted in Figure 4.7.2.2-1.

1.1 Process Roll Command (Section 4.7.2.2.1).

1.2 If (FLATTURN = ON), then process Touchdown and Roll-out (Section 4.7.2.2.2).

B. Interface Requirements. The input/output parameters associated with lateral guidance command processing are presented in each appropriate subfunction as referenced above. The only input to Lateral Guidance is the flat turn indicator, FLATTURN (discrete, non-dimensional, 6.25 Hz), which is obtained from the Landing SOP. All lateral guidance outputs arise from the appropriate lateral guidance subfunction.

C. Processing Requirements. Execution of lateral guidance follows execution of longitudinal guidance (Section 4.7.2.1). Processing of lateral guidance must be executed once each guidance cycle throughout the A/L phase.

D. Initialization Requirements. None.

E. Supplemental Information. See Figure 4.7.2-1 for additional functions and their definition.

A functional flow for the Approach/Landing Lateral Guidance function is provided in section 5.1.3.

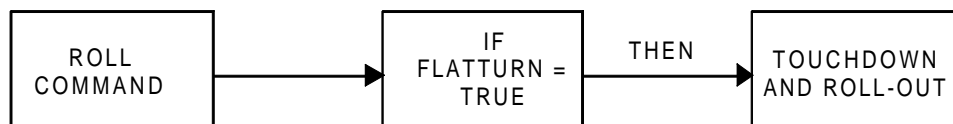


FIGURE 4.7.2.2-1. Lateral Guidance Subfunction Sequencing Requirements

4.7.2.2.1 Roll Command.

A block diagram of Roll Command subfunction is shown in Figure 4.7.2.2.1-1. The intent of the Roll Command subfunction is as follows:

1. To provide a roll attitude command angle, PHIC_AL, to the flight control subsystem.
2. To also provide the roll command, PHIC_AL, to the Touchdown and Roll-out subfunction.

The lateral roll command (PHI_CMD) is a function of the lateral error (Y) and lateral error rate (Y_DOT). For generating the roll command, PHIC_AL, to the flight control subsystem, an integral function of the lateral error may be added to the lateral command. This command integral function is functionally invoked only when the flight control system is operating in automatic mode and the lateral track mode has been initiated. When the mode is manual, then the integral output is explicitly set to zero. To enable a means to avert an undesirable roll command transient at A/L initiation (with respect to the last computed TAEM guidance roll command output), a “fader” functional capability is provided. The obtained unlimited roll command, PHIC_UL, is then limited to a magnitude dependent upon the altitude and flight control mode for final determination of the roll attitude command, PHIC_AL, output to the flight control subsystem.

A. Detailed Requirements. The logical processes of computing the equations are as follows:

1. In Equation Set 1, the integrator output Y_INT and “fader” parameters are initialized on first pass through the Roll Command subfunction.
 - 1.1 $Y_INT = 0.$
 - 1.2 $PHIC_UL = PHIC_AT$
 - 1.3 $N = N_FADER$
 - 1.4 $RC = 0.$
 - 1.5 $LAT_MODE = 1$
2. A test is made for transition to lateral track mode. Lateral track is initiated if (a) the magnitude of heading (PSI_GND) is less than the value of PSI_CAP and the magnitude of the crossrange position (Y) is less than Y_CAP or (b) the magnitude of heading (PSI_GND) is less than PSI_CAP for greater than TQ_LAT seconds. If the test is successful, the lateral mode flag is set by Equation 2.1. *** Refer to Supplemental Information for a description of a G&N incompatibility with regards to this LAT_MODE test ***.
 - 2.1 $LAT_MODE = 2$
3. The maximum allowed roll attitude command magnitude, PHI_MAX, is determined as a function of altitude and flight control mode in Equation Set 3.
 - 3.1 If (AUTORY_LAMP = ON and $H > H_WL$) then $PHI_MAX = PHI_M1$
 - 3.2 If (AUTORY_LAMP = ON and $H \leq H_WL$) then $PHI_MAX = PHI_M2$

3.3 If (AUTORY_LAMP = OFF), then $\text{PHI_MAX} = \text{PHI_M3}$

That is, PHI_MAX is determined from the following:

$$\text{PHI_MAX} = \begin{cases} \text{PHI_M1, AUTORY_LAMP} = \text{ON AND } H > H_WL \\ \text{PHI_M2, AUTORY_LAMP} = \text{ON AND } H \leq H_WL \\ \text{PHI_M3, AUTORY_LAMP} = \text{OFF} \end{cases}$$

4. The input to fader (PHI_FI) is computed in Equation Set 4.

4.1 $\text{Y_ERROR} = \text{SLIMIT}(\text{Y}, \text{Y_LIMIT})$

4.2 $\text{Y_INT_DOT} = \text{SLIMIT}(\text{Y_ERROR}, \text{Y_INLIM})$

4.3 $\text{PHI_CMD} = -K_Y1 (\text{Y_ERROR} + K_YDOT \text{Y_DOT})$

4.4 $\text{Y_INT} = \text{INTEGRAL}(\text{Y_INT_DOT})$

4.5 If (AUTORY_LAMP = OFF OR LAT_MODE = 1), then $\text{Y_INT} = 0$

4.6 $\text{PHI_FI} = \text{PHI_CMD} - A_INT \text{Y_INT}$

5. The unlimited roll command (PHIC_UL) is computed in Equation Set 5 as Equation 5.3 or Equation 5.4.

5.1 $\text{BIAS} = (\text{PHIC_UL} - \text{PHI_FI})/\text{N_FADER}$

5.2 $\text{N} = \text{N} - 1$

5.3 $\text{PHIC_UL} = \text{PHI_FI} + \text{N BIAS}$

5.4 $\text{PHIC_UL} = \text{PHI_FI}$

The logic for these equations is as follows: (a) if ($\text{N} > 0$ and $\text{N} = \text{N_FADER}$), then BIAS is initialized by Equation 5.1; (b) if ($\text{N} > 0$), then N and PHIC_UL are determined by Equations 5.2 and 5.3, respectively; and (c) if ($\text{N} \leq 0$), then PHIC_UL is determined by Equation 5.4.

6. The roll attitude command output, PHIC_AL , is computed in Equation 6.1.

6.1 $\text{PHIC_AL} = \text{SLIMIT}(\text{PHIC_UL}, \text{PHI_MAX})$

B. Interface Requirements. The input/output parameters associated with Roll Command subfunction processing are presented in Table 4.7.2.2.1-1. I-loads/constants are presented in Table 4.7.2.2.1-2.

C. Processing Requirements. Execution of the Roll Command subfunction begins with lateral guidance processing. This subfunction is processed on each guidance cycle of A/L guidance.

D. Initialization Requirements. The initialization requirements for the Roll Command subfunction are shown in Table 4.7.2.2.1-3.

E. Supplemental Information. See Table 4.7.2-2 for additional functions and their definitions.

The decision logic for transitioning from LAT_MODE = 1 to LAT_MODE = 2 currently utilizes the Navigation supplied course with respect to the runway centerline, PSI_GND. A requirement's dichotomy between A/L guidance and this Nav parameter has been found to exist as this Nav input has a range of 0 to 360 degrees while the A/L guidance LAT_MODE transition test assumes a range of -180 to +180 degrees. Hence, the guidance logic is "one-sided" as input values less than 180 degrees will reflect G&N compatibility while positive values greater than 180 degrees should always inhibit this lateral mode transition test which is contrary to the intent of the guidance functional requirements. The only effect of this potential inhibit is nonincorporation of the crossrange position error integrator command loop which is numerically dependent on the I-Load value for the integrator gain, A_INT. Currently, I-Load constraints exist which mandate that the value for A_INT be zero such that the above Nav vs. A/L guidance incompatibility is a non-issue. A software change request would be required for any corrective change if deemed necessary to satisfy A/L crossrange tracking constraints. Any such CR should also account for the corresponding deletion of the I-Load constraints against A_INT.

A functional flow for the Approach/Landing Roll Command function is provided in section 5.1.3.

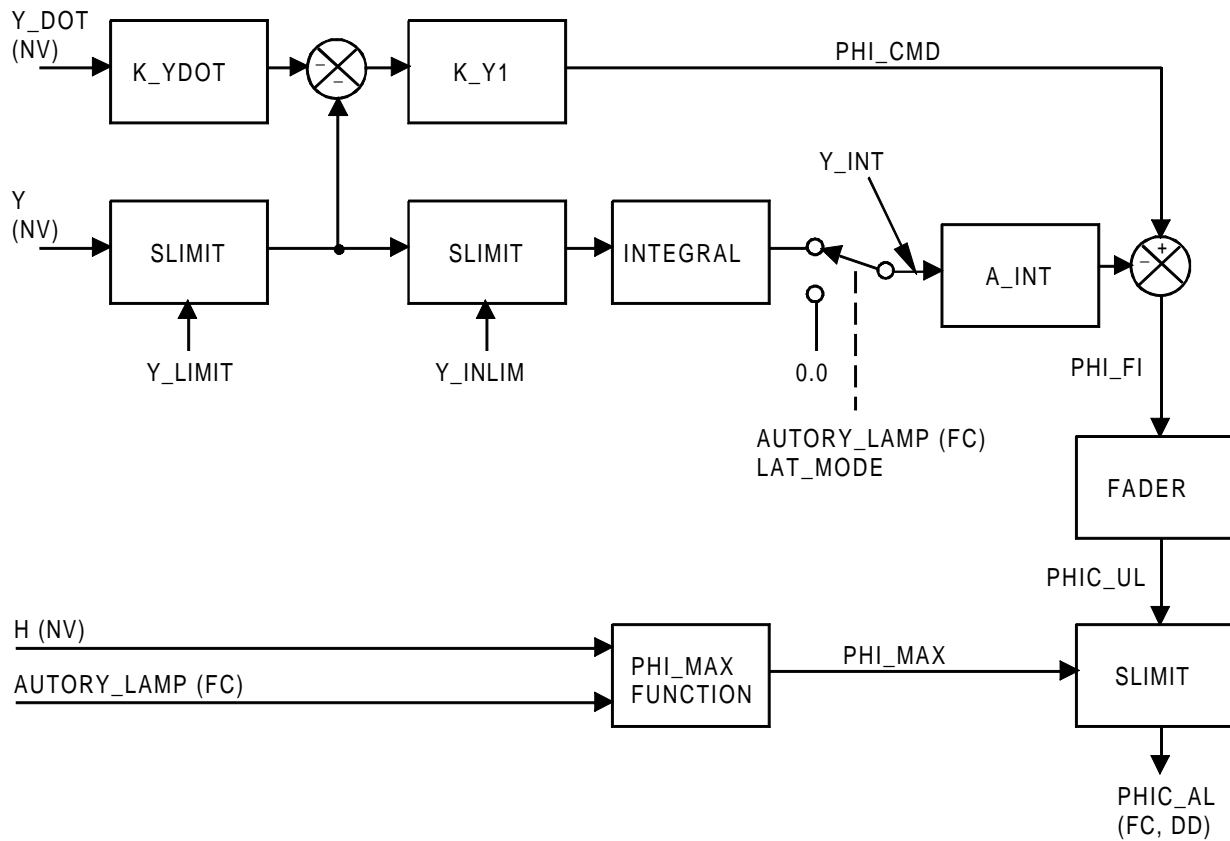


FIGURE 4.7.2.2.1-1. Roll Command Block Diagram

Table 4.7.2.2.1-1. Roll Command Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/sec)
INPUTS					
Y	Crossrange position WRT RW	NAV	F	ft	6.25
Y_DOT	Crossrange velocity WRT RW	NAV	F	ft/sec	6.25
AUTORY_LAMP	Auto lamp status, roll/yaw	AEROJET DAP	D	ND	6.25
PHIC_AT	Roll attitude command – TAEM	TAEM GUID	F	deg	*
PSI_GND	Heading wrt RW centerline	NAV	F	deg	6.25
H	Altitude of rear wheels above RW	NAV	F	ft	6.25
OUTPUTS					
PHIC_AL	Roll attitude command – AL	AEROJET DAP, E/L ADI PROC, TLM, T&R	F	deg	6.25
PHIC_UL	Unlimited roll command	TLM	F	deg	6.25
LAT_MODE	Lateral mode indicator	TLM	I	ND	6.25
RC	Yaw rate command	AEROJET DAP, TLM	F	deg/sec	6.25
*Last calculated value					

Table 4.7.2.2.1-2. Roll Command Function I-Loads/Constants						
MSID No.	Name	Description	Value	Type	Units	Class
V97U0461C	Y_LIMIT	Cross range error limit		F	ft	SX
V97U0460C	Y_INLIM	Cross range error integrator limit		F	ft	SX
V97U0315C	K_Y1	Cross range error gain		F	deg/ft	SX
V97U0000C	A_INT	Cross range error integrator gain		F	deg-sec/ft	SX
V97U0314C	K_YDOT	Cross range rate gain		F	sec	SX
V97U0320C	N_FADER	Roll fader constant		I	ND	SX
V97U0286C	H_WL	Altitude reference for roll limiter		F	ft	SX
V97U0339C	PHI_M1	Maximum roll attitude command		F	deg	SX
V97U0340C	PHI_M2	Maximum roll attitude command		F	deg	SX
V97U0341C	PHI_M3	Maximum roll attitude command		F	deg	SX
V97U0350C	PSI_CAP	Maximum heading error to engage lateral track mode	2.0	F	deg	K
V97U0416C	TQ_LAT	Minimum time with bounded error to engage lateral track mode	4.0	F	sec	K
V97U6115C	DT	A/L guidance sample time interval	0.16	F	sec	X
V97U0458C	Y_CAP	Maximum lateral error to engage lateral track mode	50.0	F	ft	K

Table 4.7.2.2.1-3. Roll Command Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Cross range integral	—	First-pass	Y_INT	0
Unlimited roll command	—	First-pass	PHIC_UL	PHIC_AT
Fader counter	—	First-pass	N	N_FADER
Lateral mode indicator	—	First-pass	LAT_MODE	1
Yaw rate command	—	First-pass	RC	0

4.7.2.2.2 Touchdown and Roll-out.

The Touchdown and Roll-out subfunction generates wings-level roll and yaw-rate RC commands to the yaw channel of the flight control subsystem to track the runway reference after flat turn initiation for touchdown and roll-out. The yaw-rate command is proportional to the roll-attitude command PHIC_AL computed in the roll command subfunction. Wings-level roll attitude commands are issued to the roll channel of the flight control subsystem.

A. Detailed Requirements.

1. Compute the yaw rate command (RC) to the flight control subsystem in Equation Set 1. The yaw rate command gain, K_R , used to compute RC is derived from a gain schedule based on dynamic pressure. The gain schedule profile is shown in Figure 4.7.2.2.2-1.
 - 1.1 Compute the yaw rate command gain, K_R , as a function of dynamic pressure, as shown in Figure 4.7.2.2.2-1.
 - 1.2 $RC = K_R PHIC_AL$
2. The roll command (PHIC_AL) is zeroed in Equation 2.1.
 - 2.1 $PHIC_AL = 0.0$

B. Interface Requirements. The input/output parameters associated with this subfunction are presented in Table 4.7.2.2.2-1. The I-loads are shown in Table 4.7.2.2.2-2.

C. Processing Requirements. Execution of Touchdown and Roll-out processing follows Roll Command processing and if flat turn has been initiated (FLATTURN = 1). The processing must continue once each guidance cycle throughout the touchdown and roll-out subphase.

D. Initialization Requirements. The initialization requirements for the Touchdown and Roll-out subfunction are shown in Table 4.7.2.2.2-3.

E. Supplemental Information. The calculation of the yaw rate command gain, K_R , using the yaw rate command gain schedule K_R_TAB is as follows:

If dynamic pressure, QBAR, has a value within the range of any two successive dynamic pressure break points in K_R_TAB , linearly interpolate between the corresponding yaw rate command gain values.

If dynamic pressure has a value at or outside the min or max dynamic pressure values defined by K_R_TAB , the appropriate yaw rate command gain value corresponding to either the minimum or maximum dynamic pressure value should be used.

A functional flow for the Approach/Landing Touchdown and Roll-out function is provided in section 5.1.3.

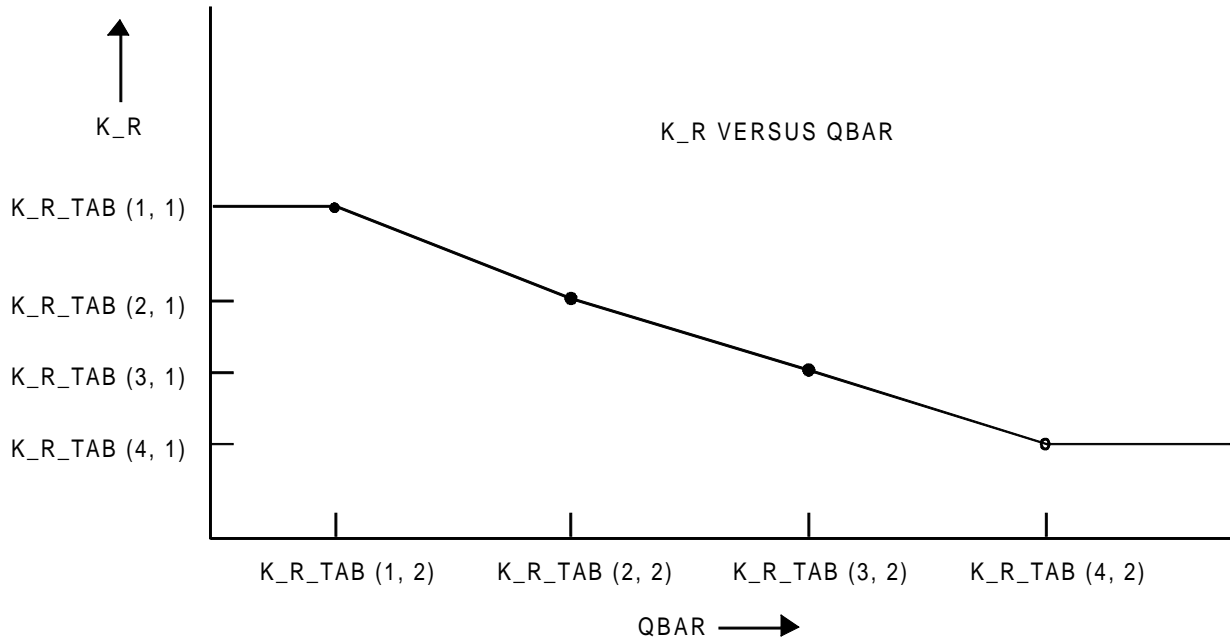


FIGURE 4.7.2.2.2-1. Yaw Rate Command Gain Schedule Profile

Table 4.7.2.2.2-1. Touchdown and Roll-out Input/Output Parameters					
Name	Description	Source/ Destination	Type	Units	Comp Rate (1/s)
INPUTS					
PHIC_AL	Roll attitude command – AL	RC	F	deg	6.25
QBAR	GN&C dynamic pressure	ADTA SOP	F	psf	1.04
OUTPUTS					
RC	Yaw rate command	AEROJET DAP, TLM	F	deg/sec	6.25
PHIC_AL	Roll attitude command – AL	AEROJET DAP, TLM	F	deg	6.25

Table 4.7.2.2.2-2. Touchdown and Roll-out Function I-Loads						
MSID No.	Name	Description	Value	Type	Units	Class
V96U9356C thru V96U9363C	K_R_ TAB(I,J)*	Yaw rate command gain schedule		F (array)	sec ⁻¹ ** psf ***	SX
* I=1, 2, 3, 4; J = 1,2		** J = 1			*** J = 2	

Table 4.7.2.2.2-3. Touchdown and Roll-out Initialization Requirements				
Component	Initialize on Transition		Variable	Initial Value
	From	To		
Yaw rate command	TAEM	A/L	RC*	0
*See Section 4.7.2.2.1.				

4.7.3 Parameter Tables for A/L Guidance (G4.10)

The IDD inputs and outputs are listed in Tables 4.7.3–1 and 4.7.3–2 respectively. Values for the I-loads are contained in the I-load requirements document (JSC–19350); however, I-load definitions applicable to this principal function are listed in Table 4.7.3–3. K-loads are listed in Table 4.7.3–4. Constants are listed in Table 4.7.3–5.

TABLE 4.7.3-1. INPUT FUNCTIONAL PARAMETERS FOR AUTOLAND GUIDANCE (G4.10)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ALT_WHEELS	V95H0165CD	ALT TO REAR WHEELS/NAV BASE(ENTRY)	A/L UPP	FT	DPL		93017G	*
AUTOP_IND/AUTOP_LAMP	V90X1632XA	PITCH AUTO FLAG	AEROJET DAP				92522D	
AUTORY_IND/AUTORY_LAMP	V90X1642XA	ROLL/YAW AUTO FLAG	AEROJET DAP				92522D	
COURSE_WRT_RW/PSD	V95H0225CC	COURSE WRT RW CENTERLINE	A/L UPP	DEG			93017G	*
EAS	V95L3145C	GN&C EQUIVALENT AIRSPEED	ADTA SOP	FT/S	SPL		93017G	*
FLATTURN_CMD	V96X0051X	FLATTURN INDICATOR	LANDING SOP					
FLT_PATH_ANG/GAMMA	V95H0261CB	GROUND-REL FLT PATH ANGLE	A/L UPP	SPECIAL			93017G	*
GI_CHANGE	V93X4476X	HEAD WIND HI/LO CMD	HORIZ SIT DISP		BD		93017G	*
H_DOT_ELLIPSOID/H_DOT	V95L0265CC	EST ALTITUDE RATE	A/L UPP	FT/S	SPL		93017G	*
I_SHORT_RW	V93J0996C	SHORT RUNWAY OPTION	HORIZ SIT DISP				93017G	*
M/CURR_ORB_MASS/MASS	V90U1961CC	CURRENT VEHICLE MASS	DEORB GUID	SLUGS			93090E	
PHIC_AT	V90H1044CB	COMMANDED ROLL ANGLE	TAEM GUID	DEG			93017G	*
POSN_WRT_RW(1)/X	V95H0220CD	DOWNRANGE DISTANCE WRT RW	A/L UPP	FT			93017G	*
POSN_WRT_RW(2)/Y	V95H0221CD	CROSSRANGE DISTANCE WRT RW	A/L UPP	FT			93017G	*
QBAR/QBAR_AD	V95P3011C	GN&C DYNAMIC PRESSURE	ADTA SOP	LBF/FT2	SPL		93017G	*
RCO_ENABLE	V93X1112X	RCO INHIBIT/ENABLE CMD	RM SWITCH/SURF FB DISP		BD		93017G	*
REL_VEL_MAG/V	V95L0151CB	GND REL VEL MAGNITUDE IN M50 SYS	A/L UPP	FT/S	SPL		93017G	*
TAS	V95L3015C	GN&C TRUE AIRSPEED	ADTA SOP	FT/S	SPL		93017G	*
VEL_WRT_RW(2)/YDOT	V95L0256CA	CROSSRANGE VEL WRT RW	A/L UPP	FT/S			93017G	*
V_GROUNDSPEED/VH	V95L0178CD	GROUNDSPEED	A/L UPP	FT/S			92450C	
WOWLON_IND	V96X0050X	WEIGHT ON MAIN WHEELS INDICATOR	LANDING SOP		BD		93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.7.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM AUTOLAND GUIDANCE (G4.10)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
DELTA_SBE	V90U1036CA	SPBK CMD/ERROR COMPONENT	TLM	DEG				
DELTA_SBI	V90U1037CA	SPBK CMD/INTEGRAL ERROR COMPONENT	TLM	DEG				
DR_TOTAL	V90L1084CA	PROJECTED ENERGY RANGE AT TD	TLM	FT				
DSBC_AL	V90H1011CB	SPEEDBRAKE ANGLE COMMAND-AUTO LAND	AEROJET DAP DL FMT 23/1 SPI PROC VERT SIT DIP	DEG			93017G	*
EAS_FILT	V90L1039CA	FILTERED EQUIVALENT AIRSPEED	TLM	FT/S				
F_MODE	V90X1040XA	FLARE &SHALLOW GLIDESLOPE MODE FLG	TLM					
GAMMA_C3	V90H1068CA	FLIGHT PATH COMMAND-FSGS	TLM	DEG				
GAMMA_C3_DOT	V90R1069CA	FLIGHT PATH COMMAND RATE-FSGS	TLM	DEG/S				
GAMMA_ERROR	V90H1067CA	FLIGHT PATH ERROR	TLM	DEG				
HUD_SB_RETRACT	V72X4044XA	HUD SPEEDBRAKE RETRACT IND	HUDE1 HUDE2					
H_DOT_ERROR	V90R1062CA	ALTITUDE RATE ERROR	TLM	FT/S				
H_ERROR	V90H1061CA	ALTITUDE ERROR	DL FMT 23/1 E/L ADI PROC HORIZ SIT SPEC HUD PROC	FT			93017G	*
H_REF	V90H1051CA	REFERENCE ALTITUDE	DL FMT 23/A	FT			93017G	*
H_REF_DOT	V90H1071CA	ALTITUDE RATE REFERENCE-FF	DL FMT 23/1	FT/S			93017G	*
H_REF_T	V90H1053CA	ALTITUDE REFERENCE-FSGS	TLM	FT				
H_REF_T_DOT	V90H1057CA	ALTITUDE RATE REFERENCE-FSGS	TLM	FT/S				
IGI	V90J1047CB	GROUND INTERCEPT INDEX	HUD PROC					
IGS	V90J1230CB	GLIDESLOPE INDEX	DL FMT 23/1 HUD PROC VERT SIT DIP		HXS		93017G	*
LAT_MODE	V90X1085XA	LATERAL MODE INDICATOR	DL FMT 23/1				93017G	*
NZC	V90A1025CA	NORMAL ACCEL CMD	AEROJET DAP DL FMT 23/A	G			93017G	*
NZ_C	V90A1016CA	UNLIMITED NORMAL ACCEL COMMAND	TLM	G				
NZ_C1	V90A1017CA	NORMAL ACCELERATION COMMAND ONE	TLM	G				
NZ_C1H	V90A1021CA	NORM ACCEL CMD ALT RATE ERROR COMP	TLM	G				
NZ_C1I	V90A1022CA	NORM ACCEL CMD ONE INTEGRAL COMP	TLM	G				
NZ_C2H	V90A1023CA	NORM ACC CMD TWO ALT ERR COMP	TLM	G				
NZ_C2I	V90A1024CA	NORM ACCEL CMD TWO INTEGRAL COMP	TLM	G				
NZ_C3	V90A1019CA	NORMAL ACCELERATION COMMAND THREE	TLM	G				
NZ_C4	V90A1020CA	NORMAL ACCELERATION COMMAND FOUR	TLM	G				
PHIC_AL	V90H1044CA	COMMANDED ROLL ANGLE	AEROJET DAP DL FMT 23/A E/L ADI PROC	DEG			93017G	*
PHIC_UL	V90H1031CB	UNLIMITED ROLL COMMAND	TLM	DEG				
P_MODE	V90Q1100CA	PITCH SUBPHASE MODE INDICATOR	DL FMT 23/1 HUD PROC				93017G	*
RC	V90R1027CA	AUTOLAND YAW RATE CMD	AEROJET DAP DL FMT 23/1	DEG/S			93017G	*

TABLE 4.7.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM AUTOLAND GUIDANCE (G4.10)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
RCO_DC_ARM	V90X0832X	RCO DRAG CHUTE ARM CMD	DL FMT 23/A		BD		93017G	*
RCO_DC_DEPLOY	V90X0833X	RCO DRAG CHUTE DEPLOY CMD	DL FMT 23/A GN&C/SM-PL IF		BD		93017G	*
RCO_LG_ARM	V90X0830X	RCO LANDING GEAR ARM CMD	DL FMT 23/A GN&C/SM-PL IF		BD		93017G	*
RCO_LG_DEPLOY	V90X0831X	RCO LANDING GEAR DEPLOY CMD	DL FMT 23/A GN&C/SM-PL IF		BD		93017G	*
RETRACT_BF	V90X1030XA	BF RETRACT FLAG	AEROJET DAP					
R_GND_AP	V90H1034CA	RANGE TO RUNWAY TARGET	HORIZ SIT SPEC TLM VERT SIT DIP	FT				
V_ERROR	V90L1064CA	VELOCITY ERROR	TLM	FT/S				
V_T_FILT	V90L1065CA	FILTERED TRUE AIRSPEED	TLM	FT/S				
V_WIND_FILT	V90L1083CA	FILTERED WIND SPEED	TLM	FT/S				
V_WIND_X	V90L1082CA	COMPUTED WIND SPEED	TLM	FT/S				
	V90M3175P	RCO LDG GEAR/DRG CHUTE ARM/DPL CMD	DL FMT 23/A				93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec
 (HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec

TABLE 4.7.3-3. AUTOLAND GUIDANCE (G4.10) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
A_40	V97U0005C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
A_DR_WT(1)	V99U8830C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
A_DR_WT(2)	V99U8831C	FT	F	S	M	P	G4.10	00	GL3	DC2356	
A_INT	V97U0000C	DEG*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
A_VWF	V99U8820C	SEC**-1	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
B_DR_WT(1)	V99U8832C	FT/SLUG	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
B_DR_WT(2)	V99U8833C	FT/SLUG	F	S	M	P	G4.10	00	GL3	DC2356	
DSBC_WW	V96U9365C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
DT_LAG_NZ	V96U9364C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
GAMMA_REF_1(1)	V97U0233C	DEG	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
GAMMA_REF_1(2)	V97U0234C	DEG	F	S	M	C	G4.10 G4.252	00	GL3	92938B	
GAMMA_REF_2	V97U0235C	DEG	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
H_CLOOP	V97U0265C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_DECAY	V97U0266C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_ERROR_MAX	V97U0269C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_FF	V97U0270C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_FLARE	V97U0271C	FT	F	S	M	C	G4.10 G4.234	00	GLC	90960E	
H_INTMX	V97U0272C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_K(1,1)	V97U0273C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
H_K(1,2)	V97U0274C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
H_K(2,1)	V97U0275C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
H_K(2,2)	V97U0276C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
H_MIN	V97U0277C	FT	F	S	D	C	G4.10 G4.234	00	ZFH	92938B	
H_NO_ACC	V97U0278C	FT	F	S	D	C	G4.10 G4.234 G4.252	00	ZFH	92938B	

TABLE 4.7.3-3. AUTOLAND GUIDANCE (G4.10) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
H_SBR_TABLE(1)	V97U0281C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_SBR_TABLE(2)	V97U0282C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_TD1_DOT	V97U0284C	FT/SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_TD2_DOT	V97U0285C	FT/SEC	F	S	D	C	G4.10 G4.234 G4.252	00	ZFH	92938B	
H_WL	V97U0286C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
INIT_RET_BF	V97U0492C	ND	BI		M	P	G4.10 G4.234	01 03	ZFH ZFH	DC2711	
K_DH	V99U8822C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_DR_DH	V99U8823C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_DR_SRW(1)	V97U1293C	FT	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
K_DR_SRW(2)	V97U1294C	FT	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
K_FLR	V97U0299C	G*SEC**2/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_FF	V97U0303C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_FSGS	V97U0304C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_SGS	V97U0305C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_TC	V97U0306C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HINT1	V97U0307C	G/FT*SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_FSGS	V97U0300C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_SGS	V97U0301C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_TC	V97U0302C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_IFLR	V97U0308C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_INT_FSGS	V97U0309C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(1,1)	V96U9356C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(1,2)	V96U9357C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	

TABLE 4.7.3-3. AUTOLAND GUIDANCE (G4.10) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
K_R_TAB(2,1)	V96U9358C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(2,2)	V96U9359C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(3,1)	V96U9360C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(3,2)	V96U9361C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(4,1)	V96U9362C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(4,2)	V96U9363C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SB	V97U0312C	DEG*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SBI	V97U0313C	DEG/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SB_DR	V99U8828C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_Y1	V97U0315C	DEG/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_YDOT	V97U0314C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
NZC_LIM	V97U0323C	G	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
N_FADER	V97U0320C	ND	I	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M1	V97U0339C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M2	V97U0340C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M3	V97U0341C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
R(1,1)	V97U0379C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
R(1,2)	V97U0380C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
R(2,1)	V97U0381C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
R(2,2)	V97U0382C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
RCO_EAS_DC	V97U3401C	FT/SEC	F	S	D	P	G4.10	00	RCO	93100C	
RCO_H_ARM	V97U0198C	FT	F	S	D	P	G4.10	00	RCO	93100C	
RCO_H_GEAR	V97U3403C	FT	F	S	D	P	G4.10	00	RCO	93100C	
SB_MAX_RET	V97U1295C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
SB_MAX_TD(1)	V97U1296C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
SB_MAX_TD(2)	V97U1297C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	

TABLE 4.7.3-3. AUTOLAND GUIDANCE (G4.10) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
SB_REF	V97U0397C	DEG	F	S	D	P	G4.10	00	ZFH	DC2711	
SIGMA(1)	V97U0402C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
SIGMA(2)	V97U0403C	FT	F	S	M	C	G4.10 G4.252	00	GL3	92938B	
S_DH	V99U8824C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_DR_DH	V99U8829C	FT/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_DR_VEL	V99U8825C	FT*SEC/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_DR_WIND	V99U8826C	FT*SEC/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_SB_DR(1)	V99U8834C	DEG/FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
S_SB_DR(2)	V99U8835C	DEG/FT	F	S	M	P	G4.10	00	GL3	DC2356	
TAU_GAMMA	V97U0410C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
TAU_TD	V97U0411C	SEC	F	S	D	C	G4.10 G4.234	00	ZFH	92938B	
TAU_TD1	V97U0412C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
TAU_TD2	V97U0413C	SEC	F	S	D	P	G4.10 G4.234 G4.252	00	ZFH	DC2711	
V_REF(1)	V97U0418C	FT/SEC	F	S	M	C	G4.10 G4.234	01 03	GL1 GL3	92938B	
V_REF(2)	V97U0419C	FT/SEC	F	S	M	C	G4.10	00	GL3	92938B	
WT_GS1	V97U0444C	SLUGS	F	S	M	C	G4.10 G4.220 G4.23 G4.24 G4.25 G4.9 G5.27	00	GLC	93090E	
X_AIM_PT	V97U0445C	FT	F	S	M	C	G4.10 G4.154 G4.220 G4.234 G4.237 G4.252 G5.27 G5.7	01 03	GL1 GL3	93090E	

TABLE 4.7.3-3. AUTOLAND GUIDANCE (G4.10) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
X_EXP(1,1)	V97U0446C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
X_EXP(1,2)	V97U0447C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
X_EXP(2,1)	V97U0448C	FT	F	S	M	C	G4.10 G4.252	00	GL3	92938B	
X_EXP(2,2)	V97U0449C	FT	F	S	M	C	G4.10 G4.252	00	GL3	92938B	
X_K(1,1)	V97U0450C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
X_K(1,2)	V97U0451C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
X_K(2,1)	V97U0452C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
X_K(2,2)	V97U0453C	FT	F	S	M	P	G4.10	00	GLC	DC2287	
X_ZERO(1)	V97U0454C	FT	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
X_ZERO(2)	V97U0455C	FT	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
Y_INLIM	V97U0460C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
Y_LIMIT	V97U0461C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.7.3-4. AUTOLAND GUIDANCE (G4.10) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
A_13	V97U0002C	00	+1.0	E+00	SEC**-1	F	S	P G4.10	29579B	
A_14	V97U0003C	00	+1.0	E+00	SEC**-1	F	S	P G4.10	29579B	
A_3	V97U0004C	00	+1.0	E+01	SEC**-1	F	S	P G4.10	29579B	
GAMMA_CAPTURE	V97U0229C	00	+2.0000000	E+00	DEG	F	S	P G4.10	29579B	
H_ERROR_CAPTURE	V97U0268C	00	+5.00	E+01	FT	F	S	P G4.10	29579B	
PSI_CAP	V97U0350C	00	+2.0	E+00	DEG	F	S	P G4.10	29579B	
P_MODE_INITIAL	V97U0326C	00	+1		ND	I	S	P G4.10	29579B	
SB_MAX	V97U4145C	00	+9.86	E+01	DEG	F	S	A G4.10	93015C	
TQ_LAT	V97U0416C	00	+4.0	E+00	SEC	F	S	P G4.10	29579B	
T_Q	V97U0409C	00	+4.0	E+00	SEC	F	S	P G4.10	29579B	
V_LIMIT	V97U0417C	00	+1.00	E+01	FT/SEC	F	S	P G4.10	29579B	
Y_CAP	V97U0458C	00	+5.00	E+01	FT	F	S	P G4.10	29579B	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.7.3-5. AUTOLAND GUIDANCE (G4.10) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S	C A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DT A/L GUIDANCE SAMPLE TIME INTERVAL	V97U6115C	00	+1.6	E-01 SEC	F		S	C G4.10 G4.234	90374C	

TABLE 4.7.3-5. AUTOLAND GUIDANCE (G4.10) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S P	A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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4.8 RETURN-TO-LAUNCH-SITE (RTL) TAEM GUIDANCE (G4.204, MAJOR MODES 602 AND 603)

4.8.1 Requirements Overview

This phase contains those software functions required to guide the orbiter from the end of the $-Z$ translation burn to the approach and landing interface for an Intact abort or an ECAL abort, or to a bailout condition during a contingency abort.

An ECAL abort provides a landing capability for two engine-out situations between the first single engine-out TAL capability and the first two engine-out TAL capability as well as for three engine-out situations prior to OPS 3 capability. The ECAL abort can also be performed during RTL aborts for two engine-out situations occurring prior to powered pitch around. An ECAL abort uses several airfields along the eastern coast of the United States and Canada for landing opportunities for high inclination missions while Bermuda provides the landing opportunities for due east missions. Following dual engine failures (during the ascent portion of flight) the orbiter uses the thrust of the remaining engine to pitch up and yaw towards the landing site; this helps reduce the crossrange to be flown during entry. The purpose of the contingency abort is to guide the vehicle to a safe gliding flight condition where a bailout is generally performed.

Upon transition to MM602 which will initiate GRTL TAEM guidance processing, the vehicle is commanded to a constant high angle of attack, wings-level attitude. When the sensed normal acceleration reaches a calculated mission and altitude rate dependent value, the guidance commands a wings-level maneuver such that a desired, mission and altitude rate dependent, normal acceleration level is attained. When this maneuver is complete ($\dot{h} > \text{HDTRN}$, HDTRN = altitude rate for transition from Phase 5 to Phase 4), an alpha profile is followed until the basic TAEM guidance algorithms are initiated. During this alpha transition phase, a bank maneuver is performed either to null any heading errors to the selected heading alignment cone tangent point or to dissipate excess energy by turning away from the selected heading alignment cone. During a contingency abort, special alpha command profiles as a function of Mach number will be selected.

During the entry portion of an ECAL abort, special profiles for alpha command as a function of Mach number and energy will be selected. Also, during the NZ hold and alpha transition phases, a bank maneuver is performed to either null any heading errors to the selected heading alignment cone tangent point or to dissipate excess energy by turning towards and past the selected heading alignment cone.

For ECAL aborts, the contingency abort (CONT) and ECAL abort (ECAL) guidance flags are turned off at Mach $< \text{MSW1}$ and nominal GRTL TAEM guidance is then performed. For the purposes of this document, intact aborts are defined by the contingency abort flag being set false (CONT = OFF). A contingency abort is defined by the contingency flag being set true (CONT = ON) while the ECAL abort flag is set false (ECAL = OFF). For ECAL aborts, it is a requirement that both the contingency abort flag and the ECAL abort flags be set to true (CONT = ON and ECAL = ON).

During the TAEM guidance phase, glide range is controlled by flying to a nominal altitude and dynamic pressure reference versus range profile. Energy control is achieved by nulling out altitude errors via the normal acceleration command and by also nulling out energy errors when subsonic via the speed brake deflection command. Additional energy control is achieved by limiting the normal acceleration command based on an energy corridor formulated from a nominal energy versus range profile. The normal acceleration command is also constrained by limits based on both angle of attack and dynamic pressure. The angle of attack limits ensure that the vehicle stays within the angle-of-attack versus Mach number

corridor for lateral controllability. The dynamic pressure limits inhibit the vehicle from attaining excessively high dynamic pressures or optimize the vehicle's lift-to-drag ratio during range "stretch" maneuvers. If considerable excess energy exists, an S-turn maneuver is executed to dissipate additional energy. If the vehicle is faced with an extremely low energy situation, the guidance software sends out a flag, MEPALERT, to displays, which requests that the crew switch the heading alignment cone (HAC) to the minimum entry point (MEP) HAC location. Crew action is required to achieve relocation of the HAC.

At either the nominal or minimum entry point HAC location, the crew can toggle for the Straight-in (STRT) or the Overhead (OVHD) HAC for weather avoidance. An automatic toggling in the navigation occurs at the crossing of the runway centerline (except during the TAEM guidance heading alignment phase, IPHASE = 2) when in the Straight-in mode so that the STRT mode is maintained. Also, if a low energy condition is encountered when in the Overhead mode, a signal, OHALRT, is sent to the crew for possible redesignation to the straight-in mode. Crew action is required to achieve this change in approach mode. The OHALRT signal will go off when the energy state becomes satisfactory with respect to a calculated energy versus range reference. The navigation resets the HAC turn angle, PSHA, to an initialization value, PSHARS, when the HAC is toggled, except for toggling at the crossing of the runway centerline.

The inertial navigation and air data subsystems and the selection filter provide input data to the RTLS TAEM guidance software. A ground track predictor routine estimates the ground track distance to runway threshold. This range prediction is used to determine the energy, altitude, altitude rate, and dynamic pressure references.

The longitudinal channel commands are generated as follows:

1. During the alpha recovery phase, a constant angle of attack command is generated.
2. During the normal acceleration (NZ) hold phase, a normal acceleration command is generated as a function of time to achieve the desired constant NZ level.
3. During the alpha transition phase, an angle of attack command is generated as a linear function of Mach number. The profile used for intact aborts is different from that used for contingency aborts. For ECAL aborts, the linear contingency abort profile is biased as a function of energy (increased if high on energy, decreased if low on energy) to attempt to drive the actual energy over weight towards the energy reference profile. The pitch command is also limited to protect for a total load factor limit when necessary.
4. During the TAEM phase, a normal acceleration command is generated as a function of the altitude error and the altitude error rate error with limits based on energy over weight, dynamic pressure, and angle of attack.

During the alpha recovery, NZ hold, and alpha transition phases, the speed brake command is an open-loop function dependent on lateral stability and hinge moment considerations. During the TAEM phase, the speed brake command is generated from the energy and energy rate errors during subsonic flight, while during supersonic flight, the speed brake command is a constant. Additionally, an altitude dependent blending function is employed during closed-loop speedbrake command operations to enable a functional transition from explicit energy over weight to dynamic pressure errors to ensure compatibility with RTLS A/L speedbrake operations at the A/L interface.

For the lateral axis, if the guidance is in the alpha recovery phase or NZ hold phase during an intact abort or a contingency abort, a constant roll angle command of 0.0 degrees is generated. However if on an ECAL abort, provisions have been made to initiate a small roll command in the alpha recovery phase (at maximum negative altitude rate) if pullout loads are below specified limits and the heading error is large. Normal ECAL commands are initiated during the NZ hold phase when the altitude rate is greater than a specified value (HDTBNK). During the alpha transition phase of an intact abort or ECAL abort and during the acquisition phase of GRTLS TAEM guidance, a roll angle command that is proportional to the orbiter heading deviation from tangency to the selected heading alignment cone is generated. For ECAL aborts, the roll command during the alpha transition phase can be reduced as a function of altitude rate and altitude acceleration to indirectly protect for dynamic pressure. The roll command is also limited so that the total load factor plus the flight control nose-up compensation load factor does not exceed a maximum load factor limit. For contingency aborts a roll command of 0.0 degrees is generated during the alpha transition phase. If the guidance is in the S–turn phase, a constant roll angle command is generated. Additionally, the S–turn mode is a possible option during the alpha transition phase. In the heading alignment phase, the roll angle command is generated to assure that the orbiter performs a turn which follows the heading alignment spiral. The spiral is the ground plane projection of the cone. In the prefinal approach phase, the roll angle command is generated from a linear combination of orbiter lateral deviation and deviation rate from the runway centerline. Finally, the roll command is limited during all Nz command dependent GRTLS TAEM subphases (except the Nz Hold phase) so that the guidance Nz command plus the flight control nose–up compensation Nz command does not exceed a vehicle and weight dependent normal load limit. The Nz Hold phase does not invoke this Nz roll command limit due to its sole requirement for a 0.0 roll command.

In summary, the guidance phase designations are:

Phase 6 – alpha recovery phase

Phase 5 – NZ hold phase

Phase 4 – alpha transition phase

Phase 0 – S–turn phase of TAEM guidance

Phase 1 – acquisition phase of TAEM guidance

Phase 2 – heading alignment phase of TAEM guidance

Phase 3 – prefinal phase of TAEM guidance

The ECAL abort guidance flag will be initialized to ON or OFF in the GRINIT function via a mission specific I-Load. However if an ECAL yawing maneuver was performed during ascent (S_CONT_YAW = ON), the ECAL guidance flag will be set ON. The crew also has the capability during a contingency abort of engaging or disengaging the ECAL logic by performing an ITEM 1 on the Vertical Situation (Vert Sit1) Display in Major Mode 602. A status indicator for the ECAL mode is provided on the Vert Sit1 display. Once engaged, this flag allows special pitch and roll logic during phases 6, 5, and 4 to be enabled. Once the Mach number drops below the TAEM transition Mach number (MSW1), the ECAL flag allows the contingency abort flag (CONT) to be disabled to cause a transition to nominal GRTLS TAEM guidance.

An exception to nominal glide–range and ground–track control operations is the bailout abort mode. Due to an emergency situation, the crew may elect to bailout from the vehicle prior to landing. In order to

support this contingency egress condition, software functions are provided that enable the guidance to be configured for bailout commands. Once subsonic, the crew may invoke the bailout mode by first engaging the abort PBI with the abort mode select switch set to ATO. This action will cause the guidance to inhibit any subsequent transition to approach/land, will cause the speed brake to be commanded to retract, and will disable lateral ground-track control commands after CSS roll/yaw is engaged. Once the crew has manually established the desired air-speed and roll attitude conditions for bailout, moding the pitch and bank FCS channels to auto will complete the engagement of the bailout mode and cause the guidance to issue normal acceleration and roll commands that maintain these desired conditions. These bailout commands may be terminated by resuming manual (i.e., CSS) mode operations whereupon the normal acceleration function will revert back to nominal glide-range dependent operations although lateral ground-track control commands will remain disabled. Reengagement of automode will then again engage the bailout mode. A status indicator for the bailout mode is provided on the Vert Sit display and is driven by bailout dependent discretely output by the guidance.

To increase mission manifesting and design flexibility closer to launch when required, two I-Loads required by RTLS TAEM Guidance can be updated via pre-mission uplink. The first such uplink parameter is the initial value of the normal acceleration level at which the transition between the alpha recovery and NZ hold phases occurs. The second parameter that may be uplinked applies to the desired normal acceleration for the NZ hold phase, required by the RTLS NZ and RTLS alpha command.

4.8.2 Return-to-Launch-Site Terminal Area Energy Management Guidance

All phases of RTLS TAEM guidance are defined in this document. A wide variety of initial conditions and disturbances must be accommodated by the guidance, including variations in range and approach azimuth, altitude dispersions, wind profiles of various shapes and intensities, and turbulence. It is desired to handle off-nominal cases following an abort to the extent of the vehicle's capability to maneuver. Therefore, maximum flexibility has been designed into the software.

4.8.2.1 Software Requirements Summary.

The following subsections (4.8.2.2 through 4.8.2.16) define the detailed software requirements for the several functions and subfunctions that constitute the RTLS TAEM guidance program. Each function or subfunction is described in five subheadings:

- A. Detailed Requirements. The equations (in HAL language) and logic performed by the function are described in this subsection.
- B. Interface Requirements. Input/output parameters and I-loads/constants for each software function within RTLS TAEM guidance are shown in each subsection describing the function. Equivalent internal input names are shown in Table 4.8.2.1-1 in conjunction with the following Detailed Requirements.
- C. Processing Requirements. Processing frequency, guidance phase limits, and position in function execution sequence are indicated under this subheading. All arithmetic computations are to be done single precision.
- D. Initialization Requirements. Any flags or variables that must be initialized prior to first execution of the function are given under this subheading.
- E. Supplemental Information. This subheading contains any additional information that aids in understanding the function.

The functions and subfunctions of RTLS TAEM guidance are:

RTLS TAEM guidance (GREXEC)

RTLS TAEM guidance initialization (GRINIT)

RTLS phase transition, MEP, and OHALRT function (GRTRN)

RTLS angle of attack command function (GRALPC)

RTLS normal acceleration command function (GRNZC)

RTLS speed brake command function (GRSBC)

RTLS roll command function (GRPHIC)

XHAC function (TGXHAC)

Ground track predictor (GTP)

Resolve to 180 degrees routine (RES180)

TAEM references, dynamic pressure, and spiral adjust function (TGCOMP)

TAEM phase transition, MEP, and OHALRT function (TGTRAN)

TAEM normal acceleration command function (TGNZC)

TAEM speed brake command function (TGSBC)

TAEM roll command function (TGPHIC)

Table 4.8.2.1-1. GRTLS TAEM Guidance Input/Internal Name Equivalence				
MSID	Source Input Name	Guidance Internal Name	Description	Source
V95L0265CA	H_DOT_ELLIPSOID	HDOT	Estimated altitude rate	RTLS UPP
V95H0165CA	ALT_WHEELS	H	Alt to rear wheels	RTLS UPP
V95L0178CA	V_GROUNDSPEED	VH	Groundspeed	RTLS UPP
V95H0220CA	POSITION_WRT_RUNWAY(1)	X	Downrange distance wrt RW	RTLS UPP
V95H0221CA	POSITION_WRT_RUNWAY(2)	Y	Cross range distance wrt RW	RTLS UPP
V95L0151CA	REL_VEL_MAG	V	Ground rel vel magnitude	RTLS UPP
V95H0225CD	COURSE_WRT_RUNWAY	PSD	Course wrt RW center line	RTLS UPP
V95H0261CC	FLT_PATH_ANG	GAMMA	Ground rel flight path angle	RTLS UPP
V95U0205CA	RW_ID_UPP	RW_ID	Index of current RW	RTLS UPP
V95L0255CB	VELOCITY_WRT_RUNWAY(1)	XDOT	Downrange vel wrt RW	RTLS UPP
V95L0256CC	VELOCITY_WRT_RUNWAY(2)	YDOT	Cross range vel wrt RW	RTLS UPP
V90H2215C	COSTH	COSTH	Euler angle pitch cosine	A/E ATT PROC
V90H2202C	PHI	PHI	Body roll attitude Euler angle	A/E ATT PROC
V90H2204C	COSPHI	COSPHI	Euler angle roll cosine	A/E ATT PROC
V90R5321CA	Q_ORB	Q	Selected RGA pitch rate	SF
V90A5381C	NZ	NZ	Selected AA normal accel	SF
V95P3011C	QBAR	QBAR_AD	GN&C dynamic pressure	ADTA SOP
V95L3015C	TAS	TAS	GN&C true airspeed	ADTA SOP
V95H3021C	ALPHA	ALPHA	GN&C angle of attack	ADTA SOP
V95L3029C	M	MACH	GN&C Mach number	ADTA SOP
V95X3148X	DEF_AD	DEF_AD	Default air data flag	ADTA SOP
V93X4466X	NEP	NEP	Entry point switch cmd (a.k.a. Nominal Entry Point flag)	HORIZ SIT DISP
V93X4476X	GI_CHANGE	GI_CHANGE	Head wind high/low cmd (a.k.a. steep glide slope ground intercept redesignation flag)	HORIZ SIT DISP
V95P3170C	QBAR_N	QBAR_N	Nav derived dynamic pressure	NAVDAD SOP
V95H0181CB	PSHA	PSHA	Turn ang HAC	RTLS UPP
V95J0153CC	YSGNP	YSGN	R/L cone ind	RTLS UPP
V90X1632XB	AUTOP_LAMP	AUTOP_LAMP	Pitch axis auto indicator	GRTLS DAP
V90X1642XB	AUTORY_LAMP	AUTORY_LAMP	Roll/yaw axis auto indicator	GRTLS DAP

Table 4.8.2.1-1. GRTLS TAEM Guidance Input/Internal Name Equivalence				
MSID	Source Input Name	Guidance Internal Name	Description	Source
V90X8654X	BAILOUT_FLAG	BAILOUT_FLAG	Bailout request flag	MSC
V90X2090XA	GLIDE_RTLS_INHIBIT	CONT	RTLS contingency flag	PW RTLS GUID, PW CONT GUID, CONT 3 E/O GUID MSC
V93X0013X	MM_CODE_603	MM_603	Major Mode 603 flag	MSC
V95A0160CA	ACC_DRAG	ACC_DRAG	Drag deceleration	RTLS UPP
V93X0255XB	ECAL	ECAL	ECAL logic ena/inh discrete	VERT SIT1
V95A0170CA	ACC_VERT	ACC_VERT	Vertical acceleration	RTLS UPP
V95U0163CC	LOAD_TOTAL	LOAD_TOTAL	Total load factor	RTLS UPP
V99X6557X	S_CONT_YAW	S_CONT_YAW	Contingency yaw steering discrete	PW CONT GUID

4.8.2.2 RTLS TAEM Guidance (GREXEC).

This function is the RTLS TAEM guidance executive routine.

A. Detailed Requirements. On the first pass (INIT_PASS = OFF) or whenever the runway index is changed (RW_ID \neq RW_IDO), the initialization function (GRINIT) is executed first. Next the XHAC (TGXHAC) and the ground track predictor (GTP) functions are called. If the guidance phase indicator (IPHASE) is ≥ 4 , then Logic Set 1 is executed.

Logic Set 1

If IPHASE = 4, then the TAEM reference function (TGCOMP) is executed. After TGCOMP is executed, a test on Mach number is made, and if MACH < MSW1, then the TAEM normal acceleration command function (TGNZC) is executed. Finally, the RTLS phase transition, MEP and OHALRT function (GRTRN) is executed independent of the value of IPHASE.

After Logic Set 1 is executed, another test on IPHASE is performed. If IPHASE ≥ 4 , then Logic Set 2 is executed; otherwise Logic Set 3 is executed.

Logic Set 2

If IPHASE = 5, then the RTLS normal acceleration command function (GRNZC) is executed; otherwise the RTLS angle of attack command function (GRALPC) is executed. Next, the RTLS speed brake command function (GRSBC) is executed. Finally, the RTLS roll command function (GRPHIC) is executed, and RTLS TAEM guidance is exited.

Logic Set 3

The TAEM reference, dynamic pressure and spiral adjust function (TGCOMP) is executed. The TAEM phase transition, MEP, and OHALRT function (TGTRAN) is called. The guidance commands are then generated by calling the normal acceleration command (TGNZC), the speed brake command (TGSBC), and the roll command (TGPHIC) functions. RTLS TAEM guidance is exited.

B. Interface Requirements. The input/output parameters for GREXEC are listed in Table 4.8.2.2-1. The I-loads used in GREXEC are listed in Table 4.8.2.2-2.

C. Processing Requirements. The GREXEC function is executed at the RTLS TAEM guidance rate during major modes 602 and 603.

D. Initialization Requirements. The RTLS TAEM initialization flag, INIT_PASS, must be initialized to OFF before the first entry into GREXEC.

E. Supplemental Information. The following functions are called by GREXEC: TGXHAC, GTP, TGCOMP, TGTRAN, TGNZC, TGSBC, TGPHIC, GRTRN, GRALPC, GRINIT, GRNZC, GRSBC, and GRPHIC.

Table 4.8.2.2-1. GREXEC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
IPHASE	Guidance phase indicator	GRINIT, GRTRN, TGTRAN	ND	I
MACH	Mach number	ADTA SOP	ND	F
RW_ID	Index of current runway	NAV	ND	I
RW_IDO	Past value of runway index	GRINIT	ND	I
INIT_PASS	TAEM guidance first pass flag	GRINIT	ND	D
OUTPUTS				
INIT_PASS	TAEM guidance first pass flag	GRINIT	ND	D

Table 4.8.2.2-2. GREXEC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Type
V97U0317C	MSW1	Mach number at which NZ switching criteria for Phase 4 to Phase 1 are initiated		ND	MX

4.8.2.3 RTLS TAEM Guidance Initialization (GRINIT)

A. Detailed Requirements. The GRINIT function initializes or computes several parameters used in RTLS TAEM guidance. If (IPHASE < 4 or BAILOUT_FLAG = TRUE), then IPHASE is set to 1. Next, Equation Set 1 is executed.

- 1.1 ISR = RFTC/DTG
- 1.2 MEPALERT = OFF
- 1.3 RF = RFO
- 1.4 RTURN = RTURN0
- 1.5 PHILIM = PHILM1
- 1.6 DNZUL = DNZUC1
- 1.7 DNZLL = DNZLC1
- 1.8 QBARF = QBAR_AD
- 1.9 If DEF_AD = ON and $V > V_DEF$, then QBARF = QBAR_N
- 1.10 QBD = 0.0
- 1.11 DEF_ADO = DEF_AD
- 1.12 RW_IDO = RW_ID
- 1.13 V_PAST = V
- 1.14 TG_END = OFF
- 1.15 ISTEP4 = 1
- 1.16 PSHA = PSHAO
- 1.17 AUTOP_LAMP_PAST = AUTOP_LAMP
- 1.18 AUTORY_LAMP_PAST = AUTORY_LAMP
- 1.19 DPSAC_INIT = OFF

Next perform first pass initialization if INIT_PASS = OFF by executing Equation Set 2.

- 2.1 INIT_PASS = ON
- 2.2 SMNZ1 = SMNZC1
- 2.3 SMNZ2 = SMNZC2
- 2.4 NZSW = NZSW1

If CONT = OFF, then ECAL = OFF and Equations 2.5 and 2.6 are skipped. Otherwise, execute Equations 2.5 and 2.6.

$$2.5 \quad ECAL = ECAL_INIT$$

$$2.6 \quad \text{IF } S_CONT_YAW = ON, \text{ then } ECAL = ON$$

B. Interface Requirements. The input/output parameters for GRINIT are listed in Table 4.8.2.3-1. The I-loads/constants used in GRINIT are listed in Table 4.8.2.3-2.

C. Processing Requirements. GRINIT is executed on first pass or whenever RW_ID \neq RW_IDO (redesignation) and should be executed before any other RTLS TAEM function.

D. Initialization Requirements. The RTLS TAEM phase indicator, IPHASE, must be initialized to 6 before the first entry into GRINIT.

E. Supplemental Information. In the event of an air data system failure, two alternate sources of dynamic pressure will be available to RTLS TAEM guidance. The first source is a default dynamic pressure which is scheduled as a function of velocity and is output by the ADTA SOP when the flag DEF_AD = ON. The second source is an estimated dynamic pressure derived from the navigated altitude and velocity. When default dynamic pressure is being supplied by the ADTA SOP and $V > V_DEF$, the NAV derived dynamic pressure is used in calculating NZC limits. In all other instances, the ADTA SOP output is used for NZC limits. When DEF_AD = ON, speed brake commands are based on NAV derived dynamic pressure.

The ability to accommodate multiple glide slopes in RTLS TAEM is achieved through appropriate pre-mission I-load selection dependent on vehicle weight. The determination of glide slope and reference constants will be made consistent with approach and landing references and operations.

Table 4.8.2.3-1. GRINIT Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
RW_ID	Target runway index number	NAV	ND	I
IPHASE	TAEM phase counter	GRTRN, TGTRAN	ND	I
AUTOP_LAMP	Auto lamp status, pitchaxis	GRTLS DAP	ND	D
AUTORY_LAMP	Auto lamp status, roll/yaw axis	GRTLS DAP	ND	D
V	Ground relative velocity magnitude	NAV	ft/sec	F
CONT	RTLS contingency flag	PW CONT GUID, CONT 3 E/O GUID, PW RTLS GUID, MSC, GRTRN	ND	D
QBAR_N	NAV derived dynamic pressure	NAVDAD SOP	psf	F
DEF_AD	Default air data flag	ADTA SOP	ND	D
S_CONT_YAW	Contingency Yaw steering discrete	PW CONT GUID	ND	D
BAILOUT_FLAG	Bailout request flag	MSC	ND	D
OUTPUTS				
INIT_PASS	TAEM guidance first-pass flag	GREXEC	ND	D
MEPALERT	Energy deficiency flag	GAX	ND	D
ISR	Prefinal roll command fader counter	TGPHIC	ND	I
RF	Final turn radius of spiral	GTP, TGCOMP	ft	F
RTURN	Spiral turn radius	GTP, HORIZ SIT SPEC	ft	F
PSHA	Turn angle HAC	GTP	deg	F
PHILIM	Roll command limit	TGPHIC, GRPHIC	deg	F
DNZUL	Upper limit on normal acceleration command	TGNZC	g	F
DNZLL	Lower limit on normal acceleration command	TGNZC	g	F
QBARF	Filtered dynamic pressure	TGCOMP	psf	F
QBD	Filtered dynamic pressure rate	TGCOMP	psf/sec	F
IPHASE	phase counter	TGTRAN, TGNZC, TGCOMP, TGSBC, TGPHIC, GTP, TLM, GRTRN, GRALPC, GREXEC, GRSBC, GRPHIC, SPI PROC, VERT SIT1, VERT SIT DIP, GRTLS DAP, ASC AREA NAV, NAV, HUD PROC, E/L ADI PROC, HORIZ SIT SPEC, MEDS FC GNC XFER	ND	I

Table 4.8.2.3-1. GRINIT Input/Output Parameters

Name	Description	Source/Destination	Units	Type
AUTOP_LAMP_PAST	Past value of auto lamp status, pitch axis	TGTRAN	ND	D
AUTORY_LAMP_PAST	Past value of auto lamp status, roll/yaw axis	TGTRAN	ND	D
NZSW	Nz level at which Phase 6 to Phase 5 occurs transition	GRTRN	g	F
SMNZ1	Exponential Nz lead term	GRNZC	g	F
SMNZ2	Linear Nz lead term	GRNZC, GRALPC	g	F
RW_IDO	Past value of RW_ID	GREXEC	ND	I
DEF_ADO	Past value of DEF_AD	TGCOMP	ND	D
V_PAST	Past value of V	TGCOMP	ft/sec	F
TG_END	TAEM guidance termination flag	MSC, GRTLS DAP, E/L ADI PROC, VERT SIT DIP, HORIZ SIT SPEC, SPI PROC, VERT SIT 2, TLM, HUD PROC, NAV, MEDS FC GNC XFER	ND	D
ISTP4	Phase 4 S-turn flag	GRPHIC, GRTRN	ND	I
ECAL	ECAL logic ena/inh discrete	GRPHIC, GRALPC, GRTRN, VERT SIT1, TLM, TGCOMP	ND	D
DPSAC_INIT	ECAL High energy heading error init flag	GRPHIC	ND	D

Table 4.8.2.3-2. GRINIT I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U6116C	DTG	Time step between TAEM guidance calls	0.96	sec	X
V97U0385C	RFTC	Roll fader time constant		sec	SX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX
V97U0124C	DNZLC1	Phase 0, 1, and 2 NZC lower limit		g	SX
V97U0126C	DNZUC1	Phase 0, 1, and 2 NZC upper limit		g	SX
V97U0536C	V_DEF	NAVDAD/default QBAR switch velocity		ft/sec	MX
V96U8262C	RFO	Nominal HAC radius at PSHA = 0°		ft	SX
V96U8374C	RTURNO	Turn radius initial value		ft	SX
V96U8687C	PSHAO	Turn angle HAC initial value		deg	SX
V97U0324C	NZSW1	Initial value of NZSW	(*)	g	MX
V97U0404C	SMNZC1	Initial value of SMNZ1		g	MX
V97U0405C	SMNZC2	Initial value of SMNZ2		g	MX
V99U6517C	ECAL_INIT	ECAL logic init discrete		ND	MX

(*) Source may be pre-mission uplink.

4.8.2.4 XHAC Function (TGXHAC).

This function determines the ground intercept index (IGI), the X location of the nominal and MEP HAC centers, the HAC location depending on the NEP discrete, and the prefinal initiation range value RPRED3.

A. Detailed Requirements. The ground intercept index, IGI, is set according to the value of the GI_CHANGE discrete as shown in Equation Set 1.

1.1. $IGI = 1$

1.2. If $GI_CHANGE = TRUE$, then $IGI = 2$

The nominal and MEP HAC X positions, XF_{TC} and XM_{EP}, and the trajectory reference point, X_{ALI}, are calculated as shown in Equation Set 2.

2.1 $XF_{TC} = XA_{IGI} - HF_{TC1}/CUBC2_{1,1}$

2.2 $XALI = XA_{IGI} - CUBC1_{1,1}/CUBC2_{1,1}$

2.3 $XM_{EP} = XA_{IGI} - HM_{EP1}/CUBC2_{1,1}$

The HAC X position, X_{HAC}, based on the nominal entry point discrete, NEP, and the prefinal initiation range value, RPRED3, are calculated as shown in Equation Set 3.

3.1 $XHAC = XF_{TC}$

3.2 If $NEP = FALSE$, then $XHAC = XM_{EP}$

3.3 $RPRED3 = -XHAC + DR3$

Finally, the NEP/MEP feedback discrete for displays, NEP_FB, is set to the NEP value (i.e., $NEP_FB = NEP$).

B. Interface Requirements. The input/output parameters for TGXHAC are listed in Table 4.8.2.4-1. The I-loads are listed in Table 4.8.2.4-2.

C. Processing Requirements. TGXHAC is processed at the RTLS TAEM guidance rate.

D. Initialization Requirements. None.

Table 4.8.2.4-1. TGXHAC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
GI_CHANGE	Steep glide slope ground intercept redesignation flag	HORIZ SIT DISP	ND	D
NEP	Nominal Entry Point flag	HORIZ SIT DISP	ND	D
OUTPUTS				
XALI	Trajectory reference point	TGCOMP	ft	F
XHAC	X coordinate of HAC center	GTP, HORIZ SIT SPEC	ft	F
RPRED3	Prefinal initiation range value	TGTRAN	ft	F
NEP_FB	NEP/MEP flag	E/L ADI PROC, HORIZ SIT SPEC, HUD PROC, TLM	ND	D
IGI	Ground intercept index	HUD PROC	ND	I

Table 4.8.2.4-2. TGXHAC I-Loads					
MSID No.	Name	Description	Value	Units	Class
V97U0136C	DR3	Delta range value for RPRED3		ft	SX
V97U0291C	HFTC(1)	Altitude to determine XFTC		ft	SX
V97U0456C	XA(I)*	Steep glide slope X intercept		ft	MX
V97U0457C					
V97U0087C	CUBC1(1,1)	Cubic altitude reference constant		ft	MX
V97U0091C	CUBC2(1,1)	Cubic altitude reference constant		ND	MX
V96U8636C	HMEP(1)	Minimum entry point altitude reference		ft	SX
*I = 1,2					

4.8.2.5 Ground Track Computation (GTP).

This section describes the equations used by the ground track predictor subprogram in mathematical symbols. The detailed formulation of the ground track predictor subprogram is given in Section 4.8.2.5.A.

An essential part of the TAEM guidance concept is the prediction of ground track range to runway threshold. The method for computing ground track range is illustrated in Figure 4.8.2.5-1. As shown, the orbiter velocity vector is initially pointing away from tangency to the heading alignment cone (spiral in ground plane). The acquisition turn is defined as the turn that will align the orbiter heading tangent to the heading alignment cone. The distance, d_{AC} , along the acquisition turn is computed from geometrical equations and an estimate of the acquisition turn radius. The distance d_1 is computed from geometrical equations relating the position of the orbiter after the acquisition turn to the tangent point on the alignment cone. The distance in the heading alignment turn is computed from the turn angle in the heading alignment phase and the alignment cone radius. The distance d_T is a fixed distance from runway threshold for each of two possible downrange locations of the alignment cylinders. The two possible downrange locations of the alignment cones are referred to as the nominal and minimum entry point (MEP) locations. The two possible cross ranges with respect to the runway locations of the heading alignment cones are referred to as the Straight-in and Overhead HAC locations.

The ground track predictor estimates range-to-go by computing the segments d_{AC} , d_1 , d_{HAC} , and d_T . These segments are added to give the total predicted range. The terms that no longer apply as the approach progresses are either set to zero or dropped from the summations.

No additional range component is required for the S-turn phase because the predicted ground track during this phase is computed as if the S-turn were to cease immediately.

During Phase 3 (prefinal approach) and after the vehicle's downrange position with respect to the runway is within a predetermined value with respect to the HAC; the estimated range-to-go is based on a straight line to the runway threshold, thus

$$R_{\text{PRED}} = \sqrt{X^2 + Y^2}$$

The geometry for computing the segments d_{AC} and d_1 is given in Figure 4.8.2.5-2. The angle $\Delta \psi$ is the difference between the orbiter heading, ψ , and the heading, ψ_T , to the heading alignment cone tangency point. The heading alignment cone is a spiral in the ground plane described by: $R_{\text{TURN}} = R_F + R_1 \psi_{HA} + R_2 \psi_{HA}^2$. Given an estimate of ψ_{HA} , the spiral acquisition is simplified by assuming a circle with center at R_F and radius of R_{TURN} . The vector from the orbiter to the center of the selected heading alignment cone is computed as

$$X_{\text{CIR}} = X_{\text{HAC}} - X$$

$$Y_{\text{CIR}} = Y_{\text{SGN}} R_F - Y$$

The distance to the center of the heading alignment cone is

$$R_{\text{CIR}} = \sqrt{(X_{\text{CIR}})^2 + (Y_{\text{CIR}})^2}$$

and the straight line distance to the tangency point is

$$R_{TAN} = \sqrt{(R_{CIR})^2 - (R_{TURN})^2}$$

which is then limited so that $R_{TAN} > 0$.

The heading, ψ_C , to the center of the heading alignment cone is given by

$$\psi_C = \tan^{-1}(Y_{CIR}/X_{CIR})$$

The heading to the tangency point is then

$$\psi_T = \psi_C - Y_{SGN} \tan^{-1}(R_{TURN}/R_{TAN})$$

and the heading error is

$$\Delta\psi = \psi_T - \psi$$

An acquisition turn radius is computed as a function of a predicted average roll angle during the turn. The turn radius, R_{AC} , and the error angle, $\Delta\psi$, are used to compute the distance, d_{AC} , to be traveled during acquisition. The distance, d_1 , to the tangency point from the end of acquisition is computed by using $\Delta\psi$, R_{AC} , and R_{TAN} .

The radius of the acquisition turn, R_{AC} , is approximated by

$$R_{AC} = V_h V / (g \tan \phi_{avg})$$

where

V_h = horizontal velocity

ϕ_{AVG} = predicted average roll angle

V = velocity magnitude

The acquisition turn arc is

$$d_{AC} = R_{AC} |\Delta\psi|$$

A correction factor to account for the slow roll rate of the vehicle is then added to d_{AC} to ensure a conservative predicted range during an S-turn. This factor is computed as

$$\Delta R = V \phi_{err} / \dot{\phi}_{avg}$$

where

V = velocity magnitude

$\phi_{err} = | \phi_{cmd} - \phi |$ and where $\phi_{err} \leq \phi_{error \ limit}$ and $\phi_{cmd} = G_\phi \Delta\phi$

$\dot{\phi}_{avg}$ = constant = maximum supersonic roll rate

and then, $d_{AC} = d_{AC} + \Delta R$

The distance, d_1 , is derived from the geometry of Figure 4.8.2.5-2.

$$A = R_{AC} (1 - \cos(\Delta\psi))$$

$$B = R_{TAN} - R_{AC} |\sin(\Delta\psi)|$$

$$d_1 = \sqrt{A^2 + B^2}$$

The distance, d_1 , is then limited to R_{TAN} to ensure a reasonable predicted ground track range during S-turns near the heading alignment cone.

A. Detailed Requirements. First, calculate the runway relative downrange position with respect to the HAC center as $XCIR = XHAC - X$. If $IPHASE = 3$ and $XCIR < DR4$, then $RPRED = \text{SQRT}(X^2 + Y^2)$ and GTP is exited. Otherwise, ($IPHASE \neq 3$ or $XCIR \geq DR4$), the remaining GTP logic is processed beginning with Equation set 1.

$$1.1 \quad \text{SIGN}Y = \text{SIGN}(Y)$$

$$1.2 \quad \text{YCIR} = \text{YSGN} \text{ RF} - Y$$

$$1.3 \quad \text{RCIR} = \text{SQRT}(XCIR^2 + YCIR^2)$$

The straight-line distance to the HAC tangency point is computed by the following: If $RCIR > RTURN$, then $RTAN = \text{SQRT}(RCIR^2 - RTURN^2)$; else $RTAN = 0$.

The heading error (from a heading tangent to the HAC) is then computed by Equation Set 2.

$$2.1 \quad \text{PSC} = \text{ARCTAN2}(YCIR, XCIR)$$

$$2.2 \quad \text{PST} = (\text{PSC} - \text{YSGN} \text{ ARCTAN2}(RTURN, RTAN)) \text{ DEG_PER_RAD}$$

$$2.3 \quad \text{PST} = \text{RES180}(\text{PST})$$

$$2.4 \quad \text{DPSAC} = \text{RES180}(\text{PST} - \text{PSD})$$

The absolute value of the heading error, DPSAC , will be passed to the MEDS FC GNC XFER for the purpose of digital display on the MEDS composite flight instrument display.

$$2.4.1 \quad \text{MEDS_DPSAC} = \text{ABS}(\text{DPSAC})$$

In order to correctly calculate the HAC turn angle, PSHA , under all possible situations, a test is included which monitors the HAC turn angle input from navigation to check for an OVHD/STRT toggling condition or runway change. Under those situations, the navigation resets the HAC turn angle to an initialization value, PSHARS .

$$2.5 \quad \text{PSHAN} = -\text{PST} \text{ YSGN}$$

$$2.6 \quad \text{If } ((\text{PSHA} > \text{PSHARS} + 1 \text{ or } \text{PSHAN} < -1 \text{ or } \text{YSGN} \neq \text{SIGN}Y) \text{ and } \text{PSHA} > 90), \text{ then } \text{PSHAN} = \text{PSHAN} + 360.$$

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- 2.7 $PSHA = PSHAN$
- 2.8 $RTURN = RF + R1 PSHA + R2 PSHA^2$
- 2.9 $RPRED2 = (RF PSHA + 0.5 R1 PSHA^2 + 0.333333 R2 PSHA^3) RAD_PER_DEG$
 $- XHAC$

If $IPHASE \neq 2$ (and $IPHASE \neq 3$), the acquisition turn radius and arc length are then computed in Equation Set 3:

- 3.1 $PHAVG = PHAVGC - PHAVGS MACH$
- 3.2 $PHAVG = MIDVAL(PHAVG, PHAVGLL, PHAVGUL)$
- 3.3 $RTAC = VH V/(GO TAN(PHAVG RAD_PER_DEG))$
- 3.4 $ARCAC = RTAC ABS(DPSAC) RAD_PER_DEG$
- 3.5 $HEADCR = ABS(GPHI DPSAC - PHI)$
- 3.6 IF $HEADCR > HDCRLM$, then $HEADCR = HDCRLM$
- 3.7 $DELRNG = V HEADCR/ROLLRT$
- 3.8 $ARCAC = ARCAC + DELRNG$

If $IPHASE \neq 2$ (and $IPHASE \neq 3$), the range from the end of the acquisition turn to the HAC tangency point, RC , is next computed by Equation Set 4:

- 4.1 $A = RTAC (1. - COS(DPSAC RAD_PER_DEG))$
- 4.2 $B = RTAN - RTAC ABS(SIN(DPSAC RAD_PER_DEG))$
- 4.3 $RC = SQRT(A^2 + B^2)$
- 4.4 IF $RC > RTAN$, then $RC = RTAN$
- 4.5 $RTAN = ARCAC + RC$

Finally, the total range-to-go is calculated from $RPRED = RPRED2 + RTAN$, and GTP is then exited.

B. Interface Requirements. The input/output parameters for GTP are listed in Table 4.8.2.5-1. The I-loads/constants are listed in Table 4.8.2.5-2.

C. Processing Requirements. GTP is processed at the RTLS TAEM guidance rate when called by GREXEC.

D. Initialization Requirements. None.

E. Supplemental Information. The following function is called by GTP: RES180.

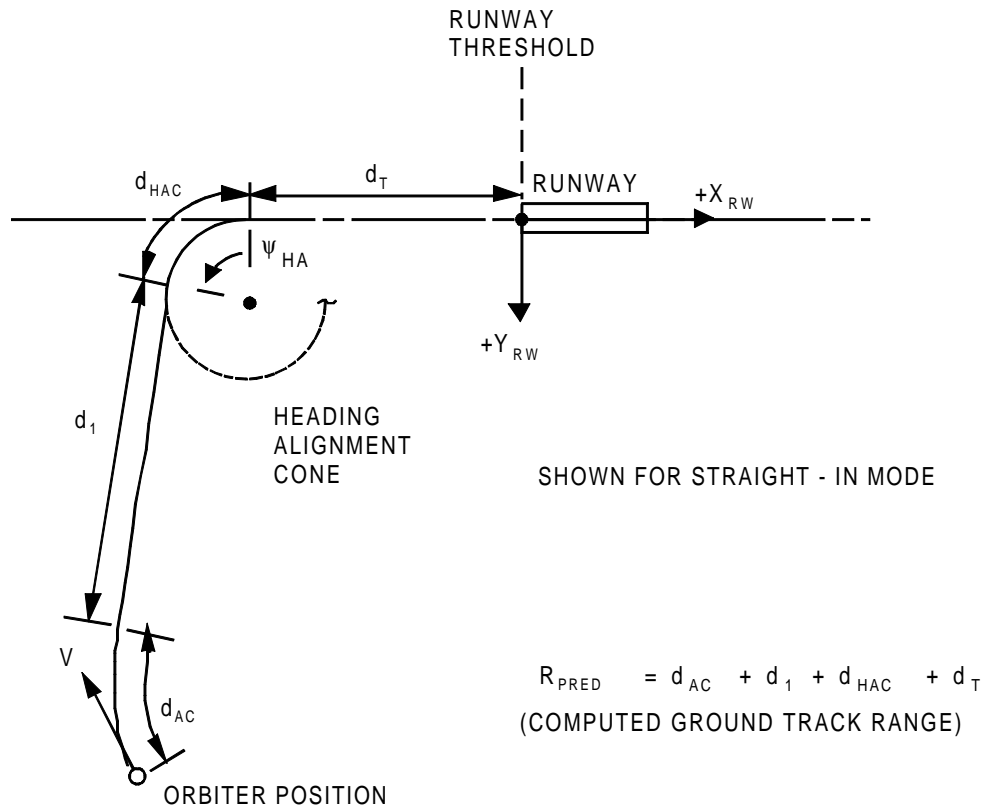


FIGURE 4.8.2.5-1. TAEM Guidance Ground Track Predictor Geometry

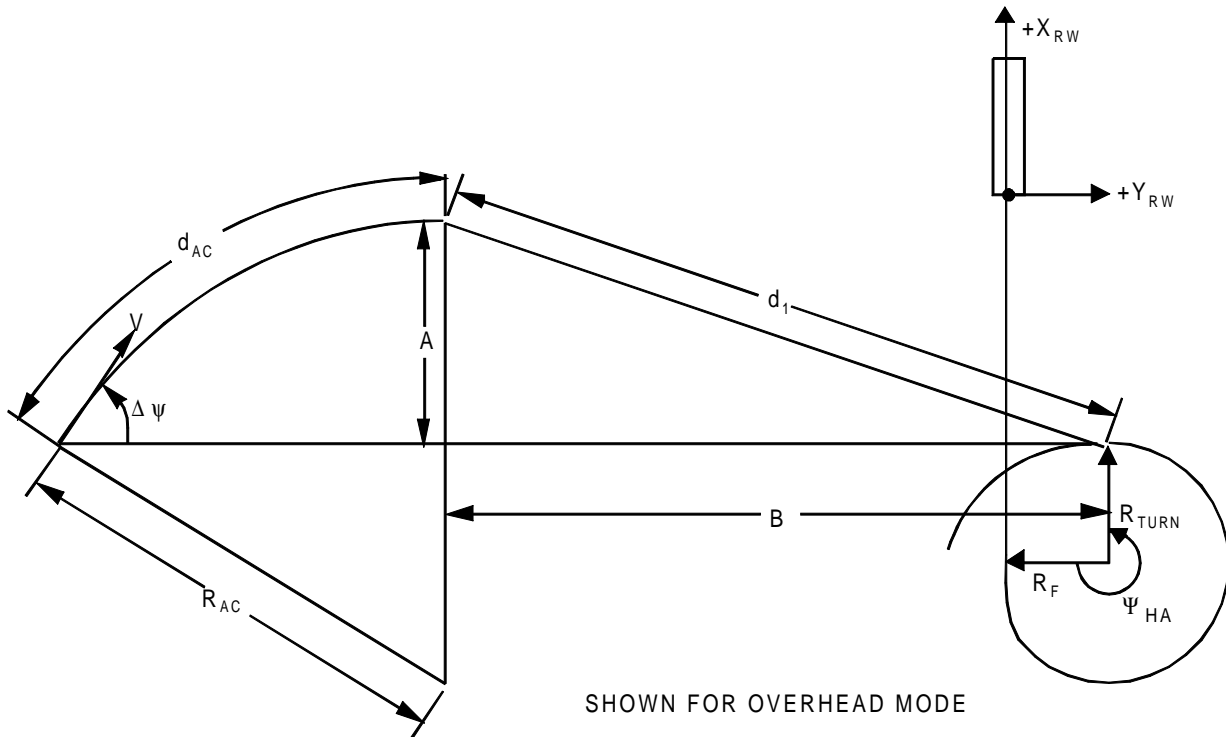


FIGURE 4.8.2.5-2. GTP for Acquisition Phase

Table 4.8.2.5-1. GTP Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
MACH	Mach number	ADTA SOP	ND	F
YSGN	Sign of crossrange position wrt runway of selected HAC	NAV	ND	F
PHI	Roll attitude	ATT PROC	deg	F
PSHA	HAC turn angle	GRINIT, NAV	deg	F
X	Downrange position wrt runway	NAV	ft	F
XHAC	X position of the HAC center	TGXHAC	ft	F
Y	Crossrange position wrt runway	NAV	ft	F
RF	Final turn radius of spiral	GRINIT, TGCOMP	ft	F
PSD	Heading of velocity vector	NAV	deg	F
RTURN	Spiral turn radius	GRINIT	ft	F
VH	Horizontal ground speed	NAV	ft/sec	F
V	Ground relative velocity magnitude	NAV	ft/sec	F
IPHASE	Guidance phase indicator	GRINIT, TGTRAN, GRTRN	ND	I
OUTPUTS				
RPRED	Total ground track range	VERT SIT DIP, HORIZ SIT SPEC, TGCOMP, TGTRAN, TLM, GRTRN	ft	F
XCIR	X distance to heading alignment cone	TGPHIC	ft	F
YCIR	Y distance to heading alignment cone	TGPHIC	ft	F
DPSAC	Heading error	TGPHIC, TLM, GRPHIC, GRALPC, E/L ADI PROC, GRTRN	deg	F
MEDS_DPSAC	MEDS Display heading error	MEDS FC GNC XFER	deg	F
RCIR	Distance to HAC center	TGTRAN, TGPHIC	ft	F
PHAVG	Average roll angle during acquisition turn	TLM	deg	F
RPRED2	Range from HAC to runway	TGCOMP, TGNZC	ft	F
PSHA	HAC turn angle	TGCOMP, TGTRAN, TGNZC, TGPHIC, GRTRN, GRPHIC	deg	F
RTAN	Straight line distance to HAC tangency point	HORIZ SIT SPEC, E/L ADI PROC	ft	F
RTURN	Spiral turn radius	TGTRAN, TGPHIC, HORIZ SIT SPEC, E/L ADI PROC, ASC AREA NAV	ft	F

Table 4.8.2.5-2. GTP I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0246C	GPHI	Acquisition roll command gain on DPSAC		ND	SX
V90A7622C	GO	Earth gravitational constant	32.174049	ft/sec ²	X
V97U0289C	HDCRLM	Maximum value of HEADCR		deg	SX
V97U0383C	RAD_PER_DEG	Degree-to-radian factor	0.017453293	rad/deg	X
V97U0391C	ROLLRT	Maximum supersonic roll rate		deg/sec	SX
V97U0112C	DEG_PER_RAD	Radian-to-degree conversion factor	57.2957795131	deg/rad	X
V97U0335C	PHAVGC	Constant for computing PHAVG		deg	SX
V97U0337C	PHAVGS	Slope for computing PHAVG		deg	SX
V97U0336C	PHAVGLL	Lower limit for PHAVG		deg	SX
V97U0338C	PHAVGUL	Upper limit for PHAVG		deg	SX
V96U8263C	R1	Coefficient of spiral		ft/deg	SX
V96U8264C	R2	Coefficient of spiral		ft/deg ²	SX
V96U8647C	PSHARS	PSHA reset value		deg	SX
V96U8635C	DR4	Distance from HAC for prefinal range		ft	SX

4.8.2.6 TAEM Reference, Dynamic Pressure, and Spiral Adjust Function (TGCOMP).

The TGCOMP function calculates the references for energy over weight, altitude, flight path angle tangent, and dynamic pressure as a function of predicted range-to-go (RPRED). The reference energy over weight (EN) may be lowered if necessary to target for subsonic conditions at the HAC for an estimated range-to-go at the start of the HAC phase, RPRED2, greater than the maximum range, R2MAX, for subsonic roll maneuvers (MACH < PHIM). For ECAL aborts, energy compensation (ref. Section 4.8.2.6E) is added to energy over weight during Alpha Transition (IPHASE = 4) and different energy over weight references may be calculated to account for the different energy over weight states encountered at higher Mach numbers for ECAL aborts. The function also computes the vehicle's present energy over weight, altitude error, filtered dynamic pressure, and equivalent airspeed command. The final turn radius, RF, of the HAC spiral is adjusted in the HAC phase as a function of altitude error from an altitude profile, HREFOH, that is lower than the nominal altitude reference. This lower altitude reference corresponds to an altitude profile for a 360 degree Overhead HAC. The energy over weight references are simply a set of linear segments, whereas the altitude reference comprises one linear segment (the A/L steep glide slope for RPRED < XALI) and two third-order polynomials (RPRED ≥ XALI). The altitude reference is constructed such that continuity is maintained at the range break points. The flight-path-angle tangent reference is simply then the negative of the derivative with respect to range of the altitude reference. The dynamic pressure reference is either of two limited linear relationships with range.

A. Detailed Requirements. Upon entering TGCOMP, the following computations are made:

1. The range (DRPRED) with respect to the nominal A/L interface (XALI) is computed in Equation Set 1.
 - 1.1 $DRPRED = RPRED + XALI$
2. The vehicle's energy over weight (EOW), energy over weight reference (EN), energy over weight for S-turn initiation (ES), energy over weight for S-turn termination (EST), energy over weight for minimum entry point alert (EMEP), energy over weight for overhead to straight-in downmoding (EMOH), and energy over weight references for normal acceleration command limiting (EMAX, EMIN) are calculated as shown in Equation Set 2.
 - 2.1 $EOW = H + V \sqrt{V/(2 GO)}$
 IF on an ECAL abort (CONT = ON and ECAL = ON) and IPHASE = 4, then execute Equation 2.1.1 to compensate for the effects of phugoid motion on the Orbiter's estimated energy state.
 - 2.1.1 $EOW = EOW + (ECOMPG EOW HDOT)$
 - 2.2 If $DRPRED < EOW_NP3_1$, then IEL = 4; else if $DRPRED < EOW_NP2_1$, then IEL = 3; else if $DRPRED < EOW_NP1_1$, then IEL = 2; else IEL = 1
 - 2.3 If $DRPRED < EOW_SP2_1$, then IES = 3; else if $DRPRED < EOW_SP1_1$, then IES = 2; else IES = 1
 - 2.4 If $DRPRED < EOW_STP2_1$, then IEST = 3; else if $DRPRED < EOW_STP1_1$, then IEST = 2; else IEST = 1

2.5 If $DRPRED < EOW_MP2_1$, then $IEM = 3$; else if $DRPRED < EOW_MP1_1$, then $IEM = 2$; else $IEM = 1$

IF on an ECAL abort ($CONT = ON$ and $ECAL = ON$) and $RPRED > ECLRNG1$, then execute Equations 2.12 through 2.18. Otherwise execute Equations 2.6 through 2.11 and Equations 2.17 and 2.18.

2.6 $EN = EN_C1_{1, IEL} + DRPRED EN_C2_{1, IEL} - MIDVAL(EN_C2_{1,3} (RPRED2 - R2MAX), 0, ESHFMX)$

2.7 $ES = ES1_{1, IES} + DRPRED EDRS_{1, IES}$

2.8 $EST = EST1_{1, IEST} + DRPRED EDRST_{1, IEST}$

2.9 $EMEP = EMEP_C1_{1, IEM} + DRPRED EMEP_C2_{1, IEM}$

2.10 $EMOH = EMOHC1_{1, IEM} + DRPRED EMOHC2_{1, IEM}$

2.11 Go to Equation 2.17

2.12 $EN = EN_ECLI + RPRED EN_ECLS$

2.13 $ES = ES_ECLI + RPRED ES_ECLS$

2.14 $EST = EST_ECLI + RPRED EST_ECLS$

2.15 $EMEP = EMEP_ECLI + RPRED EMEP_ECLS$

2.16 $EMOH = EMOH_ECLI + RPRED EMOH_ECLS$

2.17 $EMAX = EN + EDELNZ_1 MIDVAL(DRPRED/DEL_R_EMAX_1, EDEL C1, EDEL C2)$

2.18 $EMIN = EN - EDELNZ_1$

3. The altitude reference (HREF) and tangent of the reference flight path angle (DHDRRF) are calculated in Equation Set 3. If $DRPRED$ is less than 0.0, then Equations 3.1 and 3.2 are used; otherwise, Equations 3.3 through 3.5 are used.

3.1 $HREF = CUBC1_{1,1} + DRPRED CUBC2_{1,1}$

3.2 $DHDRRF = - CUBC2_{1,1}$

3.3 If $DRPRED < CUBRC_1$, then $ICUB = 1$ and $DRCUB = DRPRED$; otherwise; $ICUB = 2$ and $DRCUB = DRPRED - CUBRC_1$

3.4 $HREF = CUBC1_{1, ICUB} + DRCUB (CUBC2_{1, ICUB} + DRCUB (CUBC3_{1, ICUB} + DRCUB CUBC4_{1, ICUB}))$

3.5 $DHDRRF = - CUBC2_{1, ICUB} - DRCUB (2. CUBC3_{1, ICUB} + 3. DRCUB CUBC4_{1, ICUB})$

4. The dynamic pressure reference (QBREF) is computed in Equation Set 4. If DRPRED is greater than PBRCQ₁, then Equation 4.1 is used; otherwise, Equation 4.2 is used.
- 4.1 $QBREF = MIDVAL(QBRLL_1 + QBC1_1 (DRPRED - PBRCQ_1), QBRLL_1, QBRML_1)$
- 4.2 $QBREF = MIDVAL(QBRUL_1 + QBC2_1 DRPRED, QBRLL_1, QBRUL_1)$
5. The final turn radius of the spiral, RF, is updated using Equation Set 5. These calculations, though, are only done when the guidance is operating in the Heading Alignment phase and when the HAC turn angle is greater than a predetermined value, PSRF; i.e., IPHASE = 2 and PSHA > PSRF.
- 5.1 $HREFOH = HREF - MIDVAL(DHOH1 (DRPRED - DHOH2), 0, DHOH3)$
- 5.2 $DRF = DRFK (HREFOH - H)/(PSHA \text{ RAD_PER_DEG})$
- 5.3 $RF = MIDVAL(RFMN, RF + DRF, RFMX)$
6. The altitude error (HERROR), filtered dynamic pressure (QBARF), filtered dynamic pressure rate (QBD), dynamic pressure error (QBERR), and equivalent airspeed command are computed in Equation Set 6.
- 6.1 $HERROR = HREF - H$
- 6.2 $QBAR = QBAR_AD$
- 6.3 If DEF_AD = ON and V > V_DEF, then QBAR = QBAR_N
- The dynamic pressure filter previous values are reinitialized each time input source switching occurs to avoid false rate transients.
- If (DEF_AD = ON and V < V_DEF and V_PAST > V_DEF) or (V < V_DEF and DEF_AD ≠ DEF_ADO) then Equations 6.4 and 6.5 are executed.
- 6.4 $QBARF = QBAR$
- 6.5 $QBD = 0.0$
- 6.6 $DEF_ADO = DEF_AD$
- 6.7 $V_PAST = V$
- 6.8 $QBARD = MIDVAL(CQG (QBAR - QBARF), -QBARDL, QBARDL)$
- 6.9 $QBARF = QBARF + QBARD \text{ DTG}$
- 6.10 $QBD = CDEQD \text{ QBD} + CQDG \text{ QBARD}$
- 6.11 $QBERR = QBREF - QBARF$
- 6.12 If DEF_AD = ON, then QBERR = QBREF - QBAR_N

$$6.13 \quad EAS_CMD = 17.1865 \sqrt{QBREF}$$

B. Interface Requirements. The input/output parameters for TGCOMP are listed in Table 4.8.2.6-1. The I-loads/constants are listed in Table 4.8.2.6-2.

C. Processing Requirements. TGCOMP is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. QBARF and QBD are initialized to QBAR and zero, respectively, in GRINIT before the first-pass through TGCOMP.

E. Supplemental Information. For certain ECAL cases, phugoid motion causes oscillations in energy over weight which can trigger unnecessary S-Turns, preclude S-Turns from occurring when they are needed, or prolong the duration of S-Turn activity. To compensate for the effects of phugoid motion, energy compensation is added to the Orbiter's estimated energy state for OPS 6 ECAL cases during Alpha Transition (IPHASE = 4).

The energy compensation term (ECOMPG EOW HDOT) was derived empirically for the CAU SAFM project. The formula was derived by observing that negative estimated altitude rate (-HDOT) is in phase with the phugoid, and that the phugoid's amplitude is approximately proportional to energy over weight (EOW). By removing the phugoid component, a more accurate indicator to vehicle capability is provided.

An analytical version of energy compensation exists, however, this technique is more difficult to implement and no large advantage was observed by using the analytical technique over the empirical version.

After transition to MM 603 occurs (IPHASE \neq 4), energy compensation is no longer applied to energy over weight. This may result in a small step in the energy over weight term. This step may be visible to the crew on the VERT SIT 1 display. The magnitude of this step depends upon the estimated altitude rate at the time of major mode transition.

The energy compensation logic is disabled by setting the energy compensation gain I-load, ECOMPG, to zero.

Table 4.8.2.6-1. TGCOMP Input/Output Parameters

Name	Description	Source/Destination	Units	Type
INPUTS				
RPRED2	Range from HAC to runway	GTP	ft	F
IPHASE	TAEM phase counter	GRTRN, GRINIT, TGTRAN	ND	I
PSHA	HAC turn angle	GTP	deg	F
RF	Final turn radius of spiral	GRINIT	ft	F
RPRED	Predicted ground track range to the runway threshold	GTP	ft	F
XALI	Trajectory reference point	TGXHAC	ft	F
V	Ground relative velocity magnitude	NAV	ft/sec	F
H	Altitude of the wheels above the runway	NAV	ft	F
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
QBARF	Filtered dynamic pressure	GRINIT, TGCOMP	psf	F

Table 4.8.2.6-1. TGCOMP Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
QBD	Filtered dynamic pressure rate	GRINIT	psf/sec	F
QBAR_N	Nav derived dynamic pressure	NAVDAD SOP	psf	F
DEF_AD	Default air data flag OUTPUTS	ADTA SOP	ND	D
V_PAST	Past value of V	GRINIT	ft/sec	F
DEF_ADO	Past value of DEF_AD	GRINIT	ND	D
CONT	RTLS Contingency flag	PW RTLS GUID, PW CONT GUID, MSC, CONT 3 E/O GUID, GRTRN	ND	D
ECAL	ECAL logic ena/inh discrete	VERT SIT1, GRINIT, GRTRN	ND	D
HDOT	Estimated altitude rate	NAV	ft/sec	F
OUTPUTS				
HERROR	Altitude error	TGNZC, TGTRAN, TLM, HORIZ SIT SPEC, E/L ADI PROC	ft	F
DHDRRF	Reference flight path angle	TGNZC, TLM	ND	F
QBARF	Filtered dynamic pressure	TGNZC	psf	F
QBD	Filtered dynamic pressure rate	TGNZC, TLM	psf/sec	F
QBERR	Dynamic pressure error	TGTRAN, TGSBC, TLM	psf	F
EAS_CMD	Equivalent airspeed command	TLM	kt	F
EOW	Energy over weight	TGTRAN, TGNZC, GRTRN, GRPHIC, VERT SIT DIP, TGSBC	ft	F
EN	Reference energy over weight	TGNZC, VERT SIT DIP, TGSBC, GRTRN	ft	F
QBREF	Dynamic pressure reference	TLM	psf	F
HREF	Reference altitude	TLM	ft	F
ES	Energy over weight reference for S–turn initiation	TGTRAN, GRPHIC, VERT SIT DIP	ft	F
EST	Energy over weight reference for S–turn termination	TGTRAN, GRPHIC	ft	F
EMEP	Energy over weight reference for MEP alert	TGTRAN, GRTRN, VERT SIT DIP	ft	F
DRPRED	Range to nominal A/L interface	TGTRAN	ft	F
RF	Turn radius at end of spiral	GTP, HORIZ SIT SPEC, ASC AREA NAV	ft	F
EMOH	Energy over weight reference for OHALRT	TGTRAN, GRTRAN, VERT SIT DIP	ft	F
EMAX	Upper energy over weight reference for NZC limiting	TGNZC, VERT SIT DIP	ft	F
EMIN	Lower energy over weight reference for NZC limiting	TGNZC, VERT SIT DIP	ft	F

Table 4.8.2.6-1. TGCOMP Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
IEL	Energy reference index	TGSBC	ND	I

Table 4.8.2.6-2. TGCOMP I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U6116C	DTG	Time step between TAEM guidance calls	0.96	sec	X
V97U0333C	PBRCQ(1)	Range break point for QBREF		ft	MX
V97U0355C	QBARDL	Limit on QBARD		psf/sec	SX
V97U0356C	QBC1(1)	Slope of QBREF with range for range > PBRCQ		psf/ft	MX
V97U0358C	QBC2(1)	Slope of QBREF with range for range < PBRCQ		psf/ft	MX
V97U0373C	QBRL(1)	QBREF lower limit		psf	MX
V97U0375C	QBRML(1)	QBREF mid value		psf	MX
V97U0377C	QBRUL(1)	QBREF upper limit		psf	MX
V90A7622C	GO	Acceleration of gravity at sea level	32.174049	ft/sec ²	X
V97U0173C	EN_C1(1,J) ****	Constant energy used to determine EN		ft	MX
V97U0174C					
V97U0175C					
V97U0176C					
V97U0181C	EN_C2(1,J) ****	Slope of EN with range		ND	MX
V97U0182C					
V97U0183C					
V97U0184C					
V97U0077C	CQG	Constant gain used to compute QBARD		sec ⁻¹	SX
V97U0073C	CDEQD	Constant gain used to compute QBD		ND	SX
V97U0076C	CQDG	Constant gain used to compute QBD		ND	SX
V97U0202C	ECOMPG	Constant gain used to compute energy compensation		sec/ft	SX
V97U0193C	EOW_NP1(1)	Range for IEL selection		ft	MX
V97U0195C	EOW_NP2(1)	Range for IEL selection		ft	MX
V97U0197C	EOW_NP3(1)	Range for IEL selection		ft	MX
V97U0201C	EOW_SP1(1)	Range for IES selection		ft	MX
V97U0203C	EOW_SP2(1)	Range for IES selection		ft	MX
V97U0205C	EOW_STP1(1)	Range for IEST selection		ft	MX
V97U0207C	EOW_STP2(1)	Range for IEST selection		ft	MX
V97U0189C	EOW_MP1(1)	Range for IEM selection		ft	MX
V97U0191C	EOW_MP2(1)	Range for IEM selection		ft	MX
V97U0220C	ES1(1,J) ***	Constant energy over weight used to compute ES		ft	MX
V97U0221C					
V97U0222C					
V97U0536C	V_DEF	NAVDAD/default QBAR switch velocity		ft/sec	MX
V97U0147C	EDRS(1,J) ***	Slope of ES with range		ND	MX
V97U0148C					
V97U0149C					
V97U0213C	EST1(1,J) ***	Constant energy over weight used to compute EST		ft	MX
V97U0214C					
V97U0215C					

Table 4.8.2.6-2. TGCOMP I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0154C V97U0155C V97U0156C	EDRST(1,J) ***	Slope of EST with range		ND	MX
V97U0161C V97U0162C V97U0163C	EMEP_C1(1,J) ***	Constant energy over weight used to compute EMEP		ft	MX
V97U0167C V97U0168C V97U0169C	EMEP_C2(1,J) ***	Slope of EMEP with range		ND	MX
V97U0107C	CUBRC(1)	Range break point for cubic selection		ft	MX
V97U0087C V97U0088C	CUBC1(1,J)**	Cubic altitude reference constant		ft	MX
V97U0091C V97U0092C	CUBC2(1,J)**	Cubic altitude reference constant		ND	MX
V97U0095C V97U0096C	CUBC3(1,J)**	Cubic altitude reference constant		ft ⁻¹	MX
V97U0099C V97U0100C	CUBC4(1,J)**	Cubic altitude reference constant		ft ⁻²	MX
V97U0144C	EDELNZ(1)	Delta energy used in computing EMAX and EMIN		ft	MX
V97U0115C	DEL_R_ EMAX(1)	Delta range used in computing EMAX		ft	MX
V97U0142C	EDEL1	Constant used in determination of EMAX		ND	MX
V97U0143C	EDEL2	Constant used in determination of EMAX		ND	MX
V97U0383C	RAD_PER_DEG	Degree-to-radian conversion factor	0.017453293	rad/deg	X
V96U8673C	R2MAX	Maximum range on HAC to be subsonic nominal dynamic pressure		ft	SX
V96U8643C	ESHFMX	Maximum shift of HAC targeted EN		ft	SX
V96U8648C	PSRF	Maximum PSHA for adjusting RF		deg	SX
V96U8639C	DHOH1	Slope for spiral altitude reference deviation		ND	SX
V96U8640C	DHOH2	Range bias for spiral altitude reference deviation		ft	SX
V96U8641C	DHOH3	Limit for spiral altitude reference deviation		ft	SX
V96U8661C	RFMN	Minimum final HAC turn radius		ft	SX
V96U8662C	RFMX	Maximum final HAC turn radius		ft	SX
V96U8663C	DRFK	RF adjustment gain		ND	SX
V96U8688C V96U8689C V96U8690C	EMOHC1(1,J) ***	Constant energy over weight used to calculate EMOH		ft	MX
V96U8694C V96U8695C V96U8696C	EMOHC2(1,J) ***	Slope of EMOH with range		ND	MX
V99U6540C	ECLRNG1	Range breakpoint for ECAL EOW references		ft	MX
V99U6541C	EN_ECLI	Constant energy used to determine ECAL EN		ft	MX

Table 4.8.2.6-2. TGCOMP I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V99U6542C	EN_ECLS	Slope of ECAL EN with range to threshold		ND	MX
V99U6543C	ES_ECLI	Constant energy used to determine ECAL ES		ft	MX
V99U6544C	ES_ECLS	Slope of ECAL ES with range to threshold		ND	MX
V99U6545C	EST_ECLI	Constant energy used to determine ECAL EST		ft	MX
V99U6546C	EST_ECLS	Slope of ECAL EST with range to threshold		ND	MX
V99U6547C	EMEP_ECLI	Constant energy used to determine ECAL EMEP		ft	MX
V99U6548C	EMEP_ECLS	Slope of ECAL EMEP with range to threshold		ND	MX
V99U6549C	EMOH_ECLI	Constant energy used to determine ECAL EMOH		ft	MX
V99U6550C	EMOH_ECLS	Slope of ECAL EMOH with range to threshold		ND	MX
J = 1, 2 *J = 1, 2, 3 ****J = 1, 2, 3, 4					

4.8.2.7 Normal Acceleration Command Function (TGNZC).

The function TGNZC computes the incremental normal acceleration command, NZC. The command is generated from a computed altitude rate error term (HDERR) and from the altitude error input from TGCOMP. The upper and lower limits on the command are based on energy over weight, angle of attack, dynamic pressure, and TAEM phase considerations. A filter on the limited command (DNZCL) is implemented to smooth the command for all TAEM phases except prefinal (IPHASE = 3).

A deviation from normal TGNZC operations is the processing necessary to support bailout command requirements. Whenever the bailout mode is engaged in the pitch axis as reflected by the BAILOUT_PITCH flag being set to ON, the current dynamic pressure will be “snapped” and become the target dynamic pressure which will then be used to derive the normal acceleration command but within angle-of-attack constraints. Also upon bailout engagement, the Nz command output to the FCS, NZC, will be reset to the target dynamic pressure and angle-of-attack limited NZC command, DNZCL, to minimize FCS transients. If the bailout mode is subsequently disengaged (i.e., BAILOUT_PITCH set to OFF), the Nz command will reflect resumption of normal command processing requirements.

A. Detailed Requirements. Upon entering TGNZC, the unlimited normal acceleration command (DNZC) and the upper and lower dynamic pressure limits (QBMXNZ, QBMNNZ) are computed using Equation Set 1.

- 1.1 $GDH = MIDVAL(GDHC - GDHS \ H, GDHLL, GDHUL)$
- 1.2 $HDREF = VH \ DHDRRF$
- 1.3 $HDERR = HDREF - HDOT$

1.4 $DNZC = DNZCG \text{ GDH} (HDERR + HDREQG \text{ GDH} \text{ HERROR})$

Generate minimum dynamic pressure profile.

1.5 If $MACH < QMACH2$, then $MXQBWT = MIDVAL(QBWT1, QBWT2, QBWT1 + QBMSL1 (MACH - QMACH1))$, else $MXQBWT = MIDVAL(QBWT2, QBWT3, QBWT2 + QBMSL2 (MACH - QMACH2))$

1.6 $QBLL = MXQBWT \text{ WEIGHT_RTLS}$

1.7 $QBMNNZ = QBLL/MAX(SCALAR(COSPHI, CPMIN))$

Generate maximum dynamic pressure profile.

1.8 If $MACH > QBM1$, then $QBMXNZ = MIDVAL(QBMX2 + QBMXS2 (MACH - QBM2), QBMX2, QBMX3)$, else $QBMXNZ = MIDVAL(QBMX2 + QBMXS1 (MACH - QBM1), QBMX1, QBMX2)$

In the transonic energy region for an Overhead HAC approach, the maximum dynamic pressure profile is lowered to target for subsonic conditions at HAC initiation.

1.9 If $EQLOWL < EOW$ and $EOW < EQLOWU$ and $PSHA > PSOHQB$, then $QBMXNZ = MIDVAL(QBMNNZ, QBMXNZ, QBREF2_1 - PQBWRR (RPRED2 - R2MAX + (EOW - EN)/PEWRR))$

Next, the upper and lower dynamic pressure limits on the normal acceleration command are computed using Equation Set 2.

2.1 $QBG2 = MIDVAL(QBG2C1 \text{ MACH} + QBG2C2, QBG2LL, QBG2UL)$

2.2 If $(BAILOUT_PITCH = ON)$, then execute Equations 2.2.1 through 2.2.3.

2.2.1 If $(ISNAPP = OFF)$, then execute Equations 2.2.1.1 through 2.2.1.3.

2.2.1.1 $QBARS = QBARF$

2.2.1.2 $ISNAPP = ON$

2.2.1.3 $ICGUID = ON$

2.2.2 $QBMNNZ = QBARS$

2.2.3 $QBMXNZ = QBARS$

If the bailout engagement test fails (i.e., $BAILOUT_PITCH = OFF$), then the ISNAPP discrete is set to OFF.

2.3 $QBNZUL = - (QBG1 (QBMNNZ - QBARF) - QBD) \text{ QBG2}$

2.4 $QBNZLL = - (QBG1 (QBMXNZ - QBARF) - QBD) \text{ QBG2}$

If (IPHASE = 3 and BAILOUT_PITCH = OFF), then NZC = MIDVAL(DNZC, QBNZLL, QBNZUL). Otherwise (IPHASE ≠ 3 or BAILOUT_PITCH = ON), DNZC limits based on energy over weight and angle of attack are calculated, and the unlimited command is then limited by the energy over weight, angle of attack, and dynamic pressure limits and then filtered as shown in Equation Set 3.

- 3.1 $EOWNZUL = (GDH \text{ GEUL} (EMAX - EOW) + HDERR) GDH \text{ GEHDUL}$
- 3.2 $EOWNZLL = (GDH \text{ GELL} (EMIN - EOW) + HDERR) GDH \text{ GEHDLL}$
- 3.3 If MACH < ALPC1, then ALPUL = MIDVAL(ALPC2 MACH + ALPC3, ALPC4, ALPC5); otherwise, ALPUL = MIDVAL(ALPC6 MACH + ALPC7, ALPC8, ALPC9)
- 3.4 If MACH < ALPC10, then ALPLL = MIDVAL(ALPC11 MACH + ALPC12, ALPC13, ALPC14); otherwise if MACH < ALPC15, then ALPLL = MIDVAL(ALPC16 MACH + ALPC17, ALPC18, ALPC19); otherwise ALPLL = MIDVAL(ALPC20 MACH + ALPC21, ALPC22, ALPC23)
- 3.5 $ALPNZUL = (ALPG1 (ALPUL - ALPHA) - Q) ALPG2$
- 3.6 $ALPNZLL = (ALPG1 (ALPLL - ALPHA) - Q) ALPG2$
- 3.7 $DNZCL = MIDVAL (DNZC, EOWNZLL, EOWNZUL)$
- 3.8 $DNZCL = MIDVAL(DNZCL, ALPNZLL, ALPNZUL)$
- 3.9 $DNZCL = MIDVAL(DNZCL, QBNZLL, QBNZUL)$
- 3.10 If (BAILOUT_PITCH = ON), then execute Equations 3.10.1 through 3.10.5.
 - 3.10.1 $ALPH = MIDVAL(ALPHA, 0.0, ALPQL)$
 - 3.10.2 $ALPNZUL = (ALPE1 (ALPCMDL - ALPH) - Q) ALPE2$
 - 3.10.3 $DNZCL = MIDVAL(DNZCL, -5.0, ALPNZUL)$
 - 3.10.4 If (ICGUID = ON) then NZC = DNZCL
 - 3.10.5 ICGUID = OFF
- 3.11 $DNZCD = MIDVAL((DNZCL - NZC) CQG, -DNZCDL, DNZCDL)$
- 3.12 $NZC = NZC + DNZCD DTG$

Next, NZC is limited between the upper and lower phase dependent limits (DNZLL, DNZUL) by $NZC = MIDVAL(NZC, DNZLL, DNZUL)$.

B. Interface Requirements. The input/output parameters for TGNZC are listed in Table 4.8.2.7-1. The I-loads/constants are listed in Table 4.8.2.7-2.

C. Processing Requirements. TGNZC is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. NZC is initialized in GRNZC and GRTRN. ICGUID and ISNAPP flags must be initialized to OFF prior to first pass through TGNZC.

Table 4.8.2.7-1. TGNZC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
INPUTS				
H	Altitude of rear wheels above runway	NAV	ft	F
ALPHA	Angle of attack	ADTA SOP	deg	F
VH	Horizontal component of ground relative velocity	NAV	ft/sec	F
HDOT	Estimated altitude rate	NAV	ft/sec	F
COSPFI	Euler angle roll cosine	ATT PROC	ND	F
MACH	GN&C Mach number	ADTA SOP	ND	F
IPHASE	TAEM phase counter	GRINIT, TGTRAN, GRTRN	ND	I
DHDRRF	Tangent of the reference flight path angle	TGCOMP	ND	F
HERROR	Altitude error	TGCOMP	ft	F
Q	Pitch rate feedback	SF	deg/sec	F
QBARF	Filtered dynamic pressure	TGCOMP	psf	F
QBD	Filtered dynamic pressure rate	TGCOMP	psf/sec	F
DNZUL	Upper limit on normal acceleration command	GRINIT, TGTRAN	g	F
DNZLL	Lower limit on normal acceleration command	GRINIT, TGTRAN	g	F
DRPRED	RPRED + XALI	TGCOMP	ft	F
EN	Reference energy over weight	TGCOMP	ft	F
EMAX	Upper energy over weight reference for NZC limiting	TGCOMP	ft	F
EMIN	Lower energy over weight reference for NZC limiting	TGCOMP	ft	F
EOW	Energy over weight	TGCOMP	ft	F
PSHA	HAC turn angle	GTP	deg	F
RPRED2	Range from HAC to runway	GTP	ft	F
BAILOUT_ PITCH	Bailout pitch flag	TGTRAN	ND	D
OUTPUTS				
NZC	Normal acceleration command	GRTLS DAP, TLM, GRTRN, TGPHIC	g	F
EOWNZLL	Energy lower limit – NZC	TLM	g	F
EOWNZUL	Energy upper limit – NZC	TLM	g	F
QBMNNZ	Lower limit on dynamic pressure	TLM	psf	F
QBMXNZ	Upper limit on dynamic pressure	TLM	psf	F

Table 4.8.2.7-1. TGNZC Input/Output Parameters				
Name	Description	Source/ Destination	Units	Type
QBNZLL	Dynamic pressure lower limit – NZC	TLM	g	F
QBNZUL	Dynamic pressure upper limit – NZC	TLM	g	F

Table 4.8.2.7-2. TGNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U6116C	DTG	Time step between TAEM guidance calls	0.96	sec	X
V97U0238C	GDHC	Constant for computing GDH		ND	SX
V97U0240C	GDHS	Slope for computing GDH		ft ⁻¹	SX
V97U0239C	GDHLL	GDH lower limit		ND	SX
V97U0241C	GDHUL	GDH upper limit		ND	SX
V97U0123C	DNZCG	Gain used to compute DNZC		g-sec/ft	SX
V97U0075C	CPMIN	Minimum value of cosine of phi used in computation of QBMNNZ		ND	SX
V97U0367C	QBMX1	Constant for computing QBMXNZ		psf	SX
V97U0371C	QBM1	Mach break point in computing QBMXNZ		ND	SX
V97U0368C	QBMX2	Constant for computing QBMXNZ		psf	SX
V96U8676C	QBMXS1	Slope of QBMXNZ with Mach ≤ QBM1		psf	SX
V97U0366C	QBMXS2	Slope of QBMXNZ for Mach > QBM1		psf	SX
V97U0372C	QBM2	Mach break point in computing QBMXNZ		ND	SX
V97U0369C	QBMX3	Constant for computing QBMXNZ		psf	SX
V97U0360C	QBG1	Gain used to compute QBNZUL and QBNZLL		sec ⁻¹	SX
V97U0122C	DNZCDL	Limit on DNZCD		g/sec	SX
V97U0290C	HDREQG	Gain on HERROR component of DNZC		sec ⁻¹	SX
V97U0245C	GEUL	Constant gain for computing EOWNZUL		sec ⁻¹	SX
V97U0244C	GELL	Constant gain for computing EOWNZLL		sec ⁻¹	SX
V97U0243C	GEHDUL	Constant gain for computing EOWNZUL		g-sec/ft	SX
V97U0242C	GEHDLL	Constant gain for computing EOWNZLL		g-sec/ft	SX
V97U0077C	CQG	Constant gain used to compute DNZCD		sec ⁻¹	SX
V97U0362C	QBG2C1	Slope of QBG2 with Mach		sec-g/psf	SX
V97U0363C	QBG2C2	Constant used to compute QBG2		sec-g/psf	SX
V96U8656C	QBWT1	Constant used to compute MXQBWT		psf/slug	SX
V96U8657C	QBWT2	Constant used to compute MXQBWT		psf/slug	SX
V96U8658C	QBWT3	Constant used to compute MXQBWT		psf/slug	SX
V96U8654C	QBMSL1	Slope of MXQBWT for MACH < QMACH2		psf/slug	SX
V96U8655C	QBMSL2	Slope of MXQBWT for MACH ≥ QMACH2		psf/slug	SX
V96U8659C	QMACH1	Mach break point for MXQBWT		ND	SX

Table 4.8.2.7-2. TGNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V96U8660C	QMACH2	Mach break point for MXQBWT		ND	SX
V96U8642C	EQLOWU	Upper limit on EOW for resetting QBMXNZ		ft	SX
V96U8671C	EQLOWL	Lower limit on EOW for resetting QBMXNZ		ft	SX
V96U8650C	PSOHBQ	Minimum value for PSHA for resetting QBMXNZ		deg	SX
V96U8652C	QBREF2(1)	Targeted dynamic pressure at R2MAX		psf	MX
V96U8673C	R2MAX	Nominal range for subsonic roll maneuvers (MACH = PHIM)		ft	SX
V96U8645C	PEWRR	Partial of EN wrt range-to-go at R2MAX		ND	SX
V96U8646C	PQBWRR	Partial of dynamic pressure wrt range-to-go at EOW = EN and MACH = PHIM		psf/ft	SX
V97U0443C	WEIGHT_ RTLS	Orbiter mass		slugs	MX
V97U0364C	QBG2LL	Minimum value of QBG2		sec-g/psf	SX
V97U0365C	QBG2UL	Maximum value of QBG2		sec-g/psf	SX
V97U0015C	ALPC1	Mach break point for computing ALPUL		ND	SX
V97U0026C	ALPC2	Slope of ALPUL with Mach		deg	SX
V97U0031C	ALPC3	Constant used to compute ALPUL		deg	SX
V97U0032C	ALPC4	Lower limit for computing ALPUL		deg	SX
V97U0033C	ALPC5	Upper limit for computing ALPUL		deg	SX
V97U0034C	ALPC6	Slope of ALPUL with Mach		deg	SX
V97U0035C	ALPC7	Constant used to compute ALPUL		deg	SX
V97U0036C	ALPC8	Lower limit for computing ALPUL		deg	SX
V97U0037C	ALPC9	Upper limit for computing ALPUL		deg	SX
V97U0016C	ALPC10	Mach break point for computing ALPLL		ND	SX
V97U0017C	ALPC11	Slope of ALPLL with Mach		deg	SX
V97U0018C	ALPC12	Constant used to compute ALPLL		deg	SX
V97U0019C	ALPC13	Lower limit for computing ALPLL		deg	SX
V97U0020C	ALPC14	Upper limit for computing ALPLL		deg	SX
V97U0021C	ALPC15	Mach break point for computing ALPLL		ND	SX
V97U0022C	ALPC16	Slope of ALPLL with Mach		deg	SX
V97U0023C	ALPC17	Constant used to compute ALPLL		deg	SX
V97U0024C	ALPC18	Lower limit for computing ALPLL		deg	SX
V97U0025C	ALPC19	Upper limit for computing ALPLL		deg	SX
V97U0027C	ALPC20	Slope of ALPLL with Mach		deg	SX
V97U0028C	ALPC21	Constant used to compute ALPLL		deg	SX
V97U0029C	ALPC22	Lower limit for computing ALPLL		deg	SX
V97U0030C	ALPC23	Upper limit for computing ALPLL		deg	SX
V97U0038C	ALPG1	Gain used to compute ALPNZLL and ALPNZUL		sec ⁻¹	SX
V97U0039C	ALPG2	Gain used to compute ALPNZLL and ALPNZUL		sec-g/deg	SX

Table 4.8.2.7-2. TGNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V99U9963C	ALPQL	Maximum angle-of-attack limit		deg	SX
V99U9964C	ALPCMDL	Maximum commanded angle-of-attack limit		deg	SX
V99U9961C	ALPE1	Gain used to compute ALPNZUL		sec ⁻¹	SX
V99U9962C	ALPE2	Gain used to compute ALPNZUL		sec- g/deg	SX

4.8.2.8 RTLS Phase Transition, MEP, and OHALRT Function (GRTRN).

This module determines the phase transitions for Phases 4 through 6 and performs any initialization required due to a phase transition. This initialization includes the determination of the reference angle of attack for RTLS TAEM (intact abort), contingency abort, and ECAL aborts. These are calculated from a linear Mach dependant schedule for intact and contingency aborts. For ECAL aborts, the linear contingency abort schedule is biased as a function of energy error (the difference between the current energy over weight (EOW) and the energy reference (EN)). The reference angle of attack for ECALs may also be altered to protect for total load factor once the first pullout is complete. This function will also check for a minimum entry point (MEP) situation and send out the MEPALERT flag to DI if required. Finally, this function will determine when the transition to normal TAEM occurs.

RTLS TAEM will be initiated in the alpha recovery phase (IPHASE = 6). After the appropriate NZ level has been achieved, or the angle of attack conditions have been satisfied, the transition to the NZ hold phase (IPHASE = 5) occurs. However, the angle of attack constraints are not included for contingency or ECAL aborts.

During the NZ hold phase, a reference angle of attack value is computed. If, for an intact abort, the current angle of attack is greater than this reference value and the altitude rate is greater than a predetermined value (HDTRN), the transition to the alpha transition phase (IPHASE = 4) occurs. For contingency and ECAL aborts, the transition to IPHASE 4 occurs once the altitude rate is more positive than a predetermined value (HDTRNA). For ECAL aborts, the transition may also occur once the altitude rate is greater than the roll initiation altitude rate for ECAL logic (HDTBNK) and the altitude acceleration becomes negative (ACC_VERT < 0.0).

During the alpha transition phase, a reference angle of attack (GRALPR) is followed until TAEM interface is achieved. For ECAL aborts the reference angle of attack is modified for energy and load factor concerns. Limits are then applied for stability and thermal constraints. The difference between the current energy over weight (EOW) and the reference energy profile (EN) is first computed (EN_DELTA). An energy bias, added to the reference angle of attack, is determined from the current energy state by one of three methods. First, if EN_DELTA is negative (EOW < EN) and the heading error to the HAC tangency point is small, then the reference angle of attack will be reduced. If the heading error is large, the reference angle of attack may or may not be biased (I-Load dependent). Second, if the EN_DELTA is positive (EOW ≥ EN), but less than a specified energy corridor value (0.0 ≤ EN_DELTA < ENLIMHI), a check on EN_DELTA rate is performed. If this rate is positive then no bias is added. However, if the rate is negative, then the reference angle of attack is reduced. Otherwise, if EN_DELTA ≥ ENLIMHI, then the reference angle of attack is increased to account for this high energy situation. Also during the alpha transition phase, an upper angle of attack reference is computed which keeps the load factor from

exceeding a specified limit. This upper angle of attack reference is used during the second pullout and for ECAL aborts only.

During the alpha transition phase, MEP and OHALRT checks are performed. The MEPALERT flag will be issued whenever EOW becomes less than the MEP value for EOW (EMEP), the NEP flag is TRUE, and EOW is less than some predetermined level (EOWL_{2,1}). The OHALRT flag will be issued whenever energy over weight is less than the OHALRT reference value (EMOH), PSHA is greater than the minimum OHALRT value (PSOHAL), the predicted range is greater than the minimum OHALRT value (RMOH), and EOW is less than EOWL_{2,1}.

The transition to the normal TAEM acquisition phase (IPHASE = 1) occurs when any one of the following three conditions is satisfied:

1. Intact abort (CONT = OFF) and MACH < MSW1
2. Contingency abort (CONT = ON and ECAL = OFF) and MM_603 = TRUE
3. ECAL abort (CONT = ON and ECAL = ON) and MACH < MSW1.

A. Detailed Requirements. If IPHASE = 6, the logic for transition to Phase 5 is executed. If NZ > NZSW + DGRNZ, then Equation Set 1 is executed:

$$1.1 \quad \text{IPHASE} = 5$$

and the function is exited; otherwise, for intact aborts (CONT = OFF), the alpha trap logic contained in Equation Set 2 is executed and the function is exited. For contingency aborts (CONT = ON and ECAL = OFF) and ECAL aborts (CONT = ON and ECAL = ON), the function is exited.

$$2.1 \quad \text{If } \text{ALPHA} > \text{ALP_TRAP_ARM}, \text{ then } \text{ITSW} = 1$$

$$2.2 \quad \text{If } \text{ITSW} = 1 \text{ and } \text{ALPHA} < \text{ALP_TRAP_TRIG}, \text{ then } \text{IPHASE} = 5$$

Otherwise (IPHASE ≠ 6), Equation Sets 1 and 2 are skipped. Equation Set 3.1 is then executed for intact aborts (CONT = OFF). For contingency aborts (CONT = ON, ECAL = OFF) or for an ECAL abort in phase five (CONT = ON, ECAL = ON, and IPHASE = 5), Equation Set 3.2 is executed.

$$3.1.1 \quad \text{GRALPR} = \text{MIDVAL}(\text{GRALPS} \text{ MACH} + \text{GRALPI}, \text{GRALPL}, \text{GRALPU})$$

$$3.1.2 \quad \text{GRALPR} = \text{MIN}(\text{SCALAR}(\text{GRALPR}/\text{ABS}(\text{COSPFI}), \text{AMAXLD}))$$

$$3.2.1 \quad \text{GRALPR} = \text{MIDVAL}(\text{GRALPSA} \text{ MACH} + \text{GRALPIA}, \text{GRALPLA}, \text{GRALPUA})$$

$$3.2.2 \quad \text{EXECUTE EQNS 3.3.10 and 3.3.11}$$

Otherwise, for an ECAL abort and IPHASE = 4, Equation Set 3.3 is executed.

$$3.3.1 \quad \text{EN_DELTA} = \text{EOW} - \text{EN}.$$

$$3.3.2 \quad \text{ENLIMHI} = \text{MIDVAL}(\text{EN_HIS} \text{ RPRED} + \text{EN_HII}, \text{ENHI_MIN}, \text{ENHI_MAX})$$

- 3.3.3 $ENLIMLO = MIDVAL(EN_LOS\ RPRED + EN_LOI, ENLO_MIN, ENLO_MAX)$
- 3.3.4 Determine the Alpha/Mach region (AMR) for the ECAL minimum alpha limit (ALPHA_MIN):
If $MACH < ALPMACH1$, then $AMR = 1$;
Otherwise, if $MACH < ALPMACH2$, then $AMR = 2$;
Otherwise, $AMR = 3$
- 3.3.5 $ALPHA_MIN = MIN(AMINS(AMR)\ MACH + AMINI(AMR), AMINUL(AMR))$
- 3.3.6 $ALPHA_MAX = MIN(AMAXS1\ MACH + AMAXI1, AMAXUL)$.
- 3.3.7 If $EN_DELTA < 0.0$, then execute Equation 3.3.7.1. If $0.0 \leq EN_DELTA < ENLIMHI$, then Equation 3.3.7.2 is executed. Otherwise ($EN_DELTA \geq ENLIMHI$), Equation 3.3.7.3 is executed.
- 3.3.7.1 If ($|DPSAC| < DPSAC2$) and ($EN_DELTA < ENLIMLO$) then, $EN_ALPHA_BIAS = ENALPL$. Otherwise, $EN_ALPHA_BIAS = EN_BIAS1$.
- 3.3.7.2 If ($EN_DELTA < EN_DELTA_OLD$) then, $EN_ALPHA_BIAS = EN_BIAS2$. Otherwise, $EN_ALPHA_BIAS = EN_BIAS3$.
- 3.3.7.3 If ($LOAD_TOTAL > TLFMX1$) then, $EN_ALPHA_BIAS = EN_BIAS4$. Otherwise, $EN_ALPHA_BIAS = ENALPU$.
- 3.3.8 $EN_DELTA_OLD = EN_DELTA$.
- 3.3.9 $GRALPR = MIDVAL (GRALPR + EN_ALPHA_BIAS, ALPHA_MIN, ALPHA_MAX)$
- 3.3.10 If $LOAD_TOTAL < TLFMX1$ and $ICNTR \geq ICNTR_LIM$, set $IPPRTF = ON$.
- 3.3.11 If $ACC_VERT < 0.0$, then increment $ICNTR = ICNTR + 1$.
- 3.3.12 $ALPHA_LF_ECAL = ALPPRT - LOAD_TOTAL$.
- 3.3.13 $ALPHA_UL = MIDVAL(ALPHA + (Q/ALPG1) + (ALPHA_LF_ECAL/(ALPG1\ ALPG2)), ALPHA_MIN, ALPHA_MAX)$

If $IPHASE = 5$, then the logic for transition to Phase 4 contained in Equation Set 4 is executed and the function is exited.

- 4.1 If on an intact abort ($CONT = OFF$) and $HDOT > HDTRN$ and $ALPHA > GRALPR$, or on a contingency abort ($CONT = ON$ and $ECAL = OFF$) and $HDOT > HDTRNA$, or on an ECAL abort ($CONT = ON$ and $ECAL = ON$) and ($HDOT > HDTRNA$ or ($HDOT > HDTBNK$ and $ACC_VERT < 0.0$)) then execute Equation Set 4.2

- 4.2.1 IPHASE = 4
- 4.2.2 QBARF = QBAR_AD
- 4.2.3 Call TGCOMP

Otherwise (IPHASE = 4), the logic for the transition to Phase 1 is executed. First, the corrected normal acceleration, CORNZ, is computed using Equation Set 5.

$$5.1 \quad \text{CORNZ} = (\text{NZ} - \text{COSTH}/\text{COSPFI}) (\text{TAS}/(\text{TAS} + \text{VCO}))$$

Then, tests on Mach, and Major Mode are made.

If on an ECAL abort (CONT = ON and ECAL = ON), Equation Set 6 is executed to allow nominal GRTLS TAEM guidance to control the TAEM portion of flight (disengage contingency and ECAL abort guidance).

- 6.1 If MACH < MSW1, then CONT = OFF and ECAL = OFF.

If MACH < MSW1 for intact aborts (CONT = OFF) or MM_603 = ON for contingency aborts (CONT = ON, ECAL = OFF), then Equation Set 7 is executed and the function is exited; otherwise, the tests for MEPALERT and OHALRT are made by executing Equation Set 8.

- 7.1 IPHASE = ISTEP4
- 7.2 NZC = CORNZ
- 8.1 If EOW < EMEP and EOW < EOWL2₁ and NEP = ON, then MEPALERT = ON; otherwise, MEPALERT = OFF
- 8.2 If EOW < EMOH and PSHA > PSOHAL and RPRED > RMOH and EOW < EOWL2₁, then OHALRT = ON; otherwise, OHALRT = OFF

B. Interface Requirements. The input/output parameters for GRTRN are listed in Table 4.8.2.8-1. The I-loads/constants are listed in Table 4.8.2.8-2.

C. Processing Requirements. GRTRN is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. IPHASE is initialized in GRINIT. ITSW, EN_ALPHA_BIAS, EN_DELTA_OLD, and ICNTR must be initialized to 0 and IPPRTF must be initialized to OFF before the first entry into GRTRN.

Table 4.8.2.8-1. GRTRN Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
PSHA	HAC turn angle	GTP	deg	F
IPHASE	TAEM phase counter	GRINIT	ND	I
NZ	Normal acceleration feedback	SF	g	F
ALPHA	Angle of attack	ADTA SOP	deg	F
MACH	GN&C Mach number	ADTA SOP	ND	F
HDOT	Estimated altitude rate	NAV	ft/sec	F
COSTH	Euler angle pitch cosine	ATT PROC	ND	F
COSPHI	Euler angle roll cosine	ATT PROC	ND	F
TAS	GN&C true airspeed	ADTA SOP	ft/sec	F
RPRED	Total ground track range	GTP	ft	F
EOW	Energy over weight	TGCOMP	ft	F
EMOH	Energy over weight reference for OHALRT	TGCOMP	ft	F
NZC	Normal acceleration command	TGNZC	g	F
EMEP	Energy over weight reference for MEP alert	TGCOMP	ft	F
ISTP4	Phase 4 S–turn flag	GRINIT, GRPHIC	ND	I
NEP	Nominal Entry Point flag	HORIZ SIT DISP	ND	D
DGRNZ	Phase 5 NZC increment based on maximum h	GRALPC	g	F
CONT	RTLS Contingency Flag	PW RTLS GUID, PW CONT GUID, MSC, CONT 3 E/O GUID	ND	D
NZSW	Nz level at which Phase 6 to Phase 5 transition occurs	GRINIT, GRALPC	g	F
MM_603	Major Mode 603 Flag	MSC	ND	D
ECAL	ECAL logic ena/inh discrete	VERT SIT 1, GRINIT	ND	D
EN	Reference energy over weight	TGCOMP	ft	F
LOAD_TOTAL	Total load factor	RTLS UPP	g	F
ACC_VERT	Altitude acceleration	RTLS UPP	ft/s ²	F
Q	Selected RGA pitch rate	SF	deg/s	F
DPSAC	Heading error to the HAC tangency point	GTP	deg	F

Table 4.8.2.8-1. GRTRN Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
OUTPUTS				
IPHASE	TAEM phase counter	TGNZC, TLM, TGSBC, GTP, TGPHIC, GRALPC, GRSBC, GRPHIC, TGTRAN, GREXEC, ASC AREA NAV, NAV, SPI PROC, VERT SIT1, VERT SIT DIP, GRTLS DAP, HUD PROC, E/L ADI PROC, HORIZ SIT SPEC, MEDS FC GNC XFER	ND	I
GRALPR	Reference angle of attack	GRALPC	deg	F
NZC	Filtered normal acceleration command	TGNZC, GRTLS DAP	g	F
MEPALERT	Energy deficiency flag	GAX	ND	D
QBARF	Filtered dynamic pressure	TGCOMP	psf	F
OHALRT	TAEM guidance downmode flag	GAX, HORIZ SIT DISP	ND	D
CONT	RTLS contingency flag	MSC, VERT SIT 1, TGCOMP, GRALPC, GRPHIC, TLM, GRINIT, ADTA SOP, GRTLS DAP	ND	D
ECAL	ECAL logic ena/inh discrete	VERT SIT 1, TGCOMP, GRALPC, GRPHIC, TLM	ND	D
ALPHA_UL	ECAL angle of attack upper limit for load factor protection	GRALPC	deg	F
IPPRTF	ECAL logic pitch protection flag	TLM, GRALPC	ND	D
EN_DELTA	Delta to nominal energy	TLM	ft	F

Table 4.8.2.8-2. GRTRN I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0041C	ALP_TRAP_ARM	Angle-of-attack value to arm alpha trap transition logic		deg	SX
V97U0251C	GRALPS	Slope of GRALPR with Mach number		deg	MX
V97U0249C	GRALPI	Constant angle of attack used to compute GRALPR		deg	MX
V97U0250C	GRALPL	Minimum value for GRALPR		deg	MX
V97U0252C	GRALPU	Maximum value for GRALPR		deg	MX
V97U0431C	VCO	Constant used in computing CORNZ		ft/sec	SX
V97U0317C	MSW1	Minimum Mach number at which the Phase 4 to Phase 1 transition occurs		ND	MX
V97U0211C	EOWL2(1)	Maximum energy over weight at which an MEP or OH alert can be issued		ft	MX
V96U7792C	HDTRN	Altitude rate for transition from Phase 5 to Phase 4		ft/sec	MX
V96U8649C	PSOHAL	Minimum PSHA to issue OHALRT		deg	SX
V96U8672C	RMOH	Minimum RPRED to issue OHALRT		ft	SX
V99U7552C	AMAXLD	Maximum value for GRALPR during banking maneuver		deg	MX
V99U5041C	GRALPSA	Slope of GRALPR with Mach (contingency abort)		deg	MX
V99U5042C	GRALPIA	Constant angle of attack (contingency abort)		deg	MX
V99U5043C	GRALPLA	Minimum value of GRALPR (contingency abort)		deg	MX
V99U5044C	GRALPUA	Maximum value of GRALPR (contingency abort)		deg	MX
V99U5045C	HDTRNA	Maximum HDOT value for transition from Phase 5 to Phase 4 (contingency abort)		ft/sec	MX
V97U3702C	ALPMACH1	Mach boundary for ALPHA_MIN computation		ND	MX
V97U3703C	ALPMACH2	Mach boundary for ALPHA_MIN computation		ND	MX
V97U3704C	AMINS(2)	Slope of ALPHA_MIN with MACH in AMR 2		deg	MX
V97U3705C	AMINI(2)	Constant used to compute ALPHA_MIN in AMR 2		deg	MX
V97U3706C	AMINS(3)	Slope of ALPHA_MIN with MACH in AMR 3		deg	MX
V97U3707C	AMINI(3)	Constant used to compute ALPHA_MIN in AMR 3		deg	MX
V97U3708C	AMINUL(2)	Upper limit for computing ALPHA_MIN in AMR 2		deg	MX
V97U3709C	AMINUL(3)	Upper limit for computing ALPHA_MIN in AMR 3		deg	MX
V99U6507C	AMINS(1)	Slope of ALPHA_MIN with Mach in AMR 1		deg	MX
V99U6506C	AMINI(1)	Constant used to compute ALPHA_MIN in AMR 1		deg	MX
V99U6508C	AMINUL(1)	Upper limit for computing ALPHA_MIN in AMR 1		deg	MX
V99U6504C	AMAXS1	Slope of ALPHA_MAX with Mach		deg	MX
V99U6503C	AMAXI1	Constant used to compute ALPHA_MAX		deg	MX
V99U6505C	AMAXUL	Upper limit for computing ALPHA_MAX		deg	MX
V99U6520C	EN_HIS	Slope of ENHILIM with RPRED		ND	MX
V99U6521C	EN_HII	Constant used to compute ENLIMHI		ft	MX
V99U6551C	ENHI_MIN	Lower limit for computing ENLIMHI		ft	MX
V99U6552C	ENHI_MAX	Upper limit for computing ENLIMHI		ft	MX

Table 4.8.2.8-2. GRTRN I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V99U6553C	EN_LOS	Slope of ENLOLIM with RPRED		ND	MX
V97U0094C	ALP_TRAP_TRIG	Angle-of-attack value to trigger alpha trap transition to Nz Hold		deg	SX
V99U6554C	EN_LOI	Constant used to compute ENLIMLO		ft	MX
V99U6555C	ENLO_MIN	Lower limit for computing ENLIMLO		ft	MX
V99U6556C	ENLO_MAX	Upper limit for computing ENLIMLO		ft	MX
V99U6516C	DPSAC2	Heading error limit for EN_ALPHA_BIAS		deg	MX
V99U6518C	ENALPL	Lower limit for computing EN_ALPHA_BIAS		deg	MX
V99U6519C	ENALPU	Upper limit for computing EN_ALPHA_BIAS		deg	MX
V99U6522C	EN_BIAS1	Low energy bias for EN_ALPHA_BIAS		deg	MX
V99U6523C	EN_BIAS2	High energy bias for EN_ALPHA_BIAS		deg	MX
V99U6524C	EN_BIAS3	High energy bias for EN_ALPHA_BIAS		deg	MX
V99U6525C	EN_BIAS4	High energy bias for EN_ALPHA_BIAS		deg	MX
V99U6530C	HDTBNK	Roll initiation altitude rate for phase 5 ECAL logic		ft/s	MX
V99U6534C	TLFMX1	Total load factor break point for computing EN_ALPHA_BIAS		g	MX
V99U6531C	ICNTR_LIM	Counter limit for EN_ALPHA_BIAS		ND	MX
V99U6502C	ALPPRT	Pitch channel load factor protection limit		g	MX
V97U0038C	ALPG1	Gain used to compute ALPHA_UL		1/s	SX
V97U0039C	ALPG2	Gain used to compute ALPHA_UL		s*g/ deg	SX

4.8.2.9 RTLS Normal Acceleration Command Function (GRNZC).

The function GRNZC computes the normal acceleration command, NZC, used during the NZ hold phase. The command is initialized at a predetermined increment below the desired NZ level. The command is then increased as a function of time to attain the desired constant Nz level. The desired constant Nz to be attained is mission dependent but includes an incremental value dependent on the maximum altitude rate during the alpha recovery phase. The gains for this module are based upon FCS response characteristics and must be changed as FCS and vehicle response characteristics change.

A. Detailed Requirements. Upon entering GRNZC, Equation Set 1 is executed to calculate the time-variant shaping parameters SMNZ1 and SMNZ2, and then these are used to calculate the normal acceleration command, NZC.

$$1.1 \quad SMNZ1 = SMNZC3 \quad SMNZ1$$

$$1.2 \quad SMNZ2 = SMNZ2 - SMNZC4$$

$$1.3 \quad \text{If } SMNZ2 < SMNZ2L, \text{ then } SMNZ2 = SMNZ2L$$

$$1.4 \quad NZC = GRNZC1 - SMNZ1 - SMNZ2 + DGRNZ$$

GRNZC is then exited.

B. Interface Requirements. The input/output parameters for GRNZC are listed in Table 4.8.2.9-1. The I-loads/constants are listed in Table 4.8.2.9-2.

C. Processing Requirements. GRNZC is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. None.

Table 4.8.2.9-1. GRNZC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
DGRNZ	Phase 5 NZC increment based on maximum \dot{h}	GRALPC	g	F
SMNZ1	Exponential Nz lead term	GRINIT, GRALPC	g	F
SMNZ2	Linear Nz lead term	GRINIT	g	F
OUTPUTS				
NZC	Normal acceleration command	GRTLS DAP, TLM, TGNZC	g	F

Table 4.8.2.9-2. GRNZC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0406C	SMNZC3	Coefficient used to compute SMNZ1		ND	MX
V97U0407C	SMNZC4	Constant normal acceleration used to compute SMNZ2		g	MX
V97U0408C	SMNZ2L	Minimum value of SMNZ2		g	MX
V97U0254C	GRNZC1	Desired normal acceleration for the NZ hold phase	(*)	g	MX

(*) Source may be pre-mission uplink.

4.8.2.10 RTLS Angle-of-Attack Command Function (GRALPC).

This module computes the RTLS TAEM angle-of-attack command for the FCS for the alpha recovery phase (IPHASE = 6) and the alpha transition phase (IPHASE = 4). During the alpha recovery phase, the command is a constant value for intact aborts and is scheduled with Mach number for contingency aborts and ECALs. During the alpha transition phase, the command is initialized to the current angle of attack. It is then linearly ramped to a reference angle of attack, which is a linear function of Mach number. If on an ECAL abort (CONT = ON and ECAL = ON) and the load factor is small, the commanded angle of attack can be ramped to meet the reference angle of attack at a faster rate. Once this reference is achieved, it is followed for the rest of the phase. Also, during the alpha recovery phase, this module calculates an incremental NZ value to be added to the premission selected NZ command profile used during the NZ hold phase (IPHASE = 5). This delta NZ increment is calculated based on the maximum (most negative) sensed altitude rate during the alpha recovery phase. If on a contingency abort or ECAL abort, a target Nz based on the maximum negative altitude rate achieved during the pullout is calculated and held during the Nz hold phase. If on an ECAL abort, this target Nz may be increased where large heading errors exist and an increased target Nz is tolerable. This will allow for early banking to reduce heading error. The early banking will cause an increase in dynamic pressure. However, by pulling more g's (increase target Nz) the dynamic pressure is reduced. The target Nz may also be increased to protect for thermal concerns within a I-loaded Mach region, if an increased target Nz is tolerable.

A. Detailed Requirements. If IPHASE = 6, the constant alpha recovery angle-of-attack command, ALPCMD, as well as the altitude rate dependent incremental NZ command, DGRNZ, for the load relief phase (IPHASE = 5) are computed as shown in Equation Set 1.

- 1.1 If CONT = OFF then ALPCMD = ALPREC
- 1.2 If CONT = ON then ALPCMD = MIDVAL(ALPRECS MACH + ALPRECI, ALPRECU, ALPRECL)
- 1.3 If HDOT < HDMAX, then HDMAX = HDOT

Otherwise (HDOT ≥ HDMAX) execute Equation Set 1.3 for intact aborts (CONT = OFF) or Equation Set 1.4 for contingency aborts (CONT = ON and ECAL = OFF) and ECAL aborts (CONT = ON and ECAL = ON).

- 1.3.1 $DGRNZ = MIDVAL((HDNOM - HDMAX) DHDNZ, DHDLL, DHDUL)$
- 1.3.2 $DGRNZT = GRNZC1 + DGRNZ + 1.0$
- 1.4.1 $DGRNZT = MIDVAL(DNZB - HDMAX DHDNZ, DNZMIN, DNZMAX)$
- 1.4.2 ITGTNZ = OFF
- 1.4.3 If DGRNZT > DNZTHERM, skip 1.4.3.1 and 1.4.3.2
 - 1.4.3.1 If (MACH ≥ MACHTHERM2) and (MACH ≤ MACHTHERM3), then NZTB = NZTHMBIAS2, otherwise if (MACH ≥ MACHTHERM1) and (MACH < MACHTHERM2), then NZTB = NZTHMBIAS1; otherwise NZTB = 0
 - 1.4.3.2 $DGRNZT = DGRNZT + NZTB$

- 1.4.4 If $(ECAL = ON \text{ and } ABS(DPSAC) > DPSAC1 \text{ and } DGRNZT < DNZMX1)$, then $ITGTNZ = ON$.
- 1.4.5 If $ITGTNZ = ON$, then $DGRNZT = DGRNZT + DNZ1$
- 1.4.6 $SMNZ1 = ZDT1 \ DGRNZT$
- 1.4.7 $DGRNZ = DGRNZT - GRNZC1 - 1.0$
- 1.4.8 $NZSW = GRNZC1 - SMNZ1 - SMNZ2 + 1.0$

Otherwise ($IPHASE \neq 6$), the angle-of-attack command for the alpha transition phase is computed. Equation Set 2 tests for the initial pass through the logic and initializes the command.

- 2.1 If $IGRA = 0$, then $ALPCMD = ALPHA$ and $IGRA = 1$

Next, a test on $IGRA$ is made. If $IGRA = 1$, Equation Set 3 is executed to compute the smoothed angle-of-attack command and the function is exited.

- 3.1 If $ECAL = ON$ and $LOAD_TOTAL < TLFMX1$ then:
 $DGRALP = MIDVAL(GRALPR - ALPHA, GRALL, GRALU2)$
Else:
 $DGRALP = MIDVAL(GRALPR - ALPHA, GRALL, GRALU)$
- 3.2 $ALPCMD = ALPCMD + DGRALP$
- 3.3 If $(DGRALP < 0.0 \text{ and } ALPCMD \leq GRALPR)$ or $(DGRALP > 0.0 \text{ and } ALPCMD \geq GRALPR)$ then:
 $ALPCMD = GRALPR$
 $IGRA = 2$
- 3.4 If $(ALPHA_UL < ALPCMD \text{ and } IPPRTF = ON \text{ and } ECAL = ON)$ then:
 $ALPCMD = ALPHA_UL$

Otherwise ($IGRA \neq 1$), Equation Set 4 is used to set the angle-of-attack command equal to the reference angle of attack.

- 4.1 If $(ALPHA_UL < GRALPR \text{ and } IPPRTF = ON \text{ and } ECAL = ON)$, then $ALPCMD = ALPHA_UL$; otherwise $ALPCMD = GRALPR$

The function is exited.

B. Interface Requirements. The input/output parameters for GRALPC are listed in Table 4.8.2.10-1. The I-loads/constants are listed in Table 4.8.2.10-2.

C. Processing Requirements. GRALPC is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. $IGRA$ and $DGRNZ$ must be initialized to 0 and $ITGTNZ$ must be initialized to OFF before the first entry into GRALPC.

Table 4.8.2.10-1. GRALPC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
IPHASE	TAEM phase counter	GRINIT, GRTRN	ND	I
GRALPR	Reference angle of attack	GRTRN	deg	F
ALPHA	Angle of attack	ADTA SOP	deg	F
HDOT	Estimated altitude rate	NAV	ft/sec	F
CONT	RTLS Contingency Flag	PW RTLS GUID, PW CONT GUID, MSC, GRTRN, CONT 3 E/O GUID	ND	D
MACH	GN&C Mach number	ADTA SOP	ND	F
SMNZ2	Linear Nz lead term	GRINIT	g	F
DPSAC	Heading error to the HAC tangency point	GTP	deg	F
LOAD_TOTAL	Total load factor	RTLS UPP	g	F
ECAL	ECAL logic ena/inh discrete	VERT SIT 1, GRINIT, GRTRN	ND	D
ALPHA_UL	ECAL angle of attack upper limit for load factor protection	GRTRN	deg	F
IPPRTF	ECAL logic pitch protection flag	GRTRN	ND	D
OUTPUT				
ALPCMD	Commanded angle of attack	GRTLS DAP, TLM	deg	F
DGRNZ	Phase 5 NZC increment based on maximum \dot{h}	GRTRN, GRNZC	g	F
DGRNZT	Phase 5 target Nz	VERT SIT 1, VERT SIT 2, MEDS FC GNC XFER	g	F
ITGTNZ	ECAL prebank initiation flag	GRPHIC, TLM	ND	D
NZSW	Nz level at which Phase 6 to Phase 5 transition occurs	GRTRN	g	F
SMNZ1	Exponential Nz lead term	GRNZC	g	F

Table 4.8.2.10-2. GRALPC I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0040C	ALPREC	Recovery angle of attack		deg	MX
V99U7439C	HDMAX	Maximum sink rate during alpha recovery	+7.2E +75	ft/sec	X
V99U7438C	HDNOM	Nominal maximum sink rate during alpha recovery		ft/sec	MX
V99U7437C	DHDNZ	Gain on max sink rate difference to compute DGRNZ		g-sec/ft	MX
V99U7435C	DHDLL	Lower limit on DGRNZ		g	SX
V99U7436C	DHDUL	Upper limit on DGRNZ		g	SX
V99U5046C	ALPRECS	Change in recovery angle of attack with Mach number (contingency abort)		deg	MX
V99U5047C	ALPRECI	Constant recovery angle of attack bias (contingency)		deg	MX
V99U5048C	ALPRECU	Maximum recovery angle of attack (contingency)		deg	MX
V99U5049C	ALPRECL	Minimum recovery angle of attack (contingency)		deg	MX
V99U5050C	DNZB	Target Nz constant bias (contingency)		g	MX
V99U5051C	DNZMAX	Target Nz maximum value (contingency)		g	MX
V99U5052C	DNZMIN	Target NZ minimum value (contingency)		g	MX
V99U5053C	GRALL	Minimum increment to angle of attack per guidance cycle		deg	MX
V99U5054C	GRALU	Maximum increment to angle of attack per guidance cycle		deg	MX
V97U0254C	GRNZC1	Desired normal acceleration for Nz hold phase	(*)	g	MX
V99U5055C	ZDT1	SMNZ1 percentage of target of DGRNZT (contingency)		ND	MX
V99U6515C	DPSAC1	ECAL prebank heading error limit		deg	MX
V99U6512C	DNZMX1	ECAL prebank target NZ maximum limit		g	MX
V99U6514C	DNZ1	ECAL prebank target NZ increment		g	MX
V99U6534C	TLFMX1	ECAL load factor limit to increase the maximum increment to the angle of attack		g	MX
V99U6527C	GRALU2	Maximum increment to the angle of attack per guidance cycle (ECAL)		deg	MX
V97U3710C	DNZTHERM	ECAL Thermal/NZ protection threshold		g	MX
V97U3711C	MACHTHERM1	ECAL Thermal/NZ Mach limit		ND	MX
V97U3712C	NZTHMBIAS1	ECAL Thermal/NZ bias		g	MX
V97U3713C	MACHTHERM2	ECAL Thermal/NZ Mach limit		ND	MX
V97U3714C	NZTHMBIAS2	ECAL Thermal/NZ bias		g	MX
V97U3715C	MACHTHERM3	ECAL Thermal/NZ Mach limit		ND	MX

(*) Source may be pre-mission uplink.

4.8.2.11 RTLS Speed Brake Command Function (GRSBC).

This module computes the RTLS TAEM speed brake command during the alpha recovery, NZ hold, and alpha transition phases. The speed brake command will initially be set to the speed brake position feedback value seen at first execution of GRSBC. This initial value will then be maintained until an FCS operations-dependent dynamic pressure constraint is satisfied although for contingency aborts (which include ECAL aborts), additional constraints on Mach number, altitude rate, and guidance phase must also be satisfied. Once the applicable constraint or constraints are satisfied, the command then transitions to a predetermined Mach dependent schedule. The speed brake command is thereafter generated directly from the Mach dependent schedule.

A. Detailed Requirements. Upon first pass GRSBC execution and prior to any other GRSBC processing, the speedbrake command, DSBC_AT, and the speedbrake command ramp-up parameter, DSBC_AT1, shall be initialized to the current speedbrake position feedback, DSBOFB as shown in equation 1.1. This initialization is only done at first pass execution.

$$1.1 \quad DSBC_AT, DSBC_AT1 = DSBOFB$$

For cyclic processing, a check is first made on dynamic pressure. If $QBAR_AD \leq SBQ$ then the function is exited. Next for contingency aborts, a check is made on altitude rate Mach number and guidance phase. If $CONT = ON$ and ($H DOT \leq HDSBC$ or $IPHASE = 6$ or $MACH > MACHSB$) then the function is exited. If the dynamic pressure and contingency abort tests are not satisfied (i.e. function exit criteria not met), Equation Set 2 is executed.

$$2.1 \quad DSBC_AT1 = DSBC_AT1 + DEL1SB$$

$$2.2 \quad DSBC_AT2 = MIDVAL(MACHSBS \ MACH + MACHSBI, GRSBL1, GRSBL2)$$

$$2.3 \quad DSBC_AT = MIN(SCALAR(DSBC_AT1, DSBC_AT2))$$

The function is then exited.

B. Interface Requirements. The input/output parameters for GRSBC are listed in Table 4.8.2.11-1. The I-loads/constants are listed in Table 4.8.2.11-2.

C. Processing Requirements. GRSBC is executed at the RTLS TAEM guidance rate. GRSBC must execute after the Speed Brake Position Feedback SOP (PF4.48 STS 83-0016-32).

D. Initialization Requirements. The speed brake command, DSBC_AT, and DSBC_AT1, must be initialized to DSBOFB upon first entering GRSBC.

Table 4.8.2.11-1. GRSBC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
IPHASE	TAEM phase counter	GRINIT, GRTRN	ND	I
MACH	GN&C Mach number	ADTA SOP	ND	F
QBAR_AD	GN&C dynamic pressure	ADTA SOP	psf	F
DSBOFB	Current speedbrake position feedback	SB PFB SOP	deg	F
CONT	RTLS contingency flag	PW RTLS GUID, PW CONT GUID, MSC, CONT 3EO GUID, GRTRN	ND	D
HDOT	Estimated altitude rate	NAV	ft/sec	F
OUTPUTS				
DSBC_AT	Auto speed brake command	GRTLS DAP, SPI PROC, VERT SIT DIP, TLM	deg	F

Table 4.8.2.11-2. GRSBC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0401C	SBQ	Dynamic pressure for speed brake opening		psf	SX
V97U0119C	DEL1SB	Speed brake command increment for Phases 6 and 5		deg	MX
V97U0255C	GRSBL1	Maximum allowed value of DSBC_AT		deg	MX
V97U0256C	GRSBL2	Minimum allowed value of DSBC_AT		deg	MX
V96U7785C	MACHSBS	Slope for Mach scheduled speed brake command		deg	MX
V96U7784C	MACHSBI	Constant for Mach scheduled speed brake command		deg	MX
V99U5056C	HDSBC	Altitude rate at which speed brake may be opened (contingency)		ft/sec	MX
V99U5057C	MACHSB	Mach at which speed brake may be opened (contingency)		ND	MX

4.8.2.12 RTLS Roll Command Function (GRPHIC).

This module computes the RTLS TAEM roll angle command during the alpha recovery, NZ hold, and alpha transition phases. For the alpha recovery phase and NZ hold phase of intact aborts (CONT = OFF) and contingency aborts (CONT = ON and ECAL = OFF), the command is a constant value of zero in order to hold the vehicle wings level during these phases. In the alpha transition phase of intact aborts, the command is simply proportional to the heading error from the tangency point on the heading alignment cone unless excess energy is present. In this situation, a constant roll angle command is issued which directs the vehicle away from the selected heading alignment cone tangency point. For contingency aborts, the command remains zero during the alpha transition phase.

For ECAL aborts (CONT = ON and ECAL = ON), it is possible to issue non-zero roll commands during the alpha recovery, Nz hold, and alpha transition phases. During the alpha recovery phase, a small roll command can be initiated if large heading errors exist and an increase in target Nz can be tolerated (when ITGTNZ = ON). During the Nz hold phase (after the altitude rate > HDTBNK) and alpha transition phases, the roll command is simply proportional to the heading error. If excess energy is present during the alpha transition phase, a constant roll command is issued which directs the vehicle towards and past the selected heading alignment cone. The allowable amount past the selected heading alignment cone, in terms of heading error, is a function of Mach number. When this amount of heading error is achieved, or the high energy condition has dissipated, the roll direction is reversed. While roll commands are being issued in the alpha transition phase of ECAL aborts, equations which reduce and limit these roll commands are used to protect the vehicle for dynamic pressure and load factor after the first pullout.

A. Detailed Requirements. If in the alpha transition phase and during an intact abort (IPHASE = 4 and CONT = OFF), then the roll angle command for the alpha transition phase is computed using Equation Set 1 and the function is exited.

If (intact abort and IPHASE \neq 4) or during a contingency abort (CONT = ON and ECAL = OFF), then Equation Set 2 is executed to set the roll angle command to zero, and then the function is exited.

If (ECAL = ON and IPHASE = 4 and (EOW > ES or ISTEP4 = 0)) then Equation Sets 1.2 and 1.3.B are executed to determine any ECAL high energy requirements.

Otherwise, if (ECAL = ON and (IPHASE > 4 or (IPHASE = 4 and EOW \leq ES and ISTEP4 = 1))), then Equation Set 3 is executed to generate ECAL roll commands.

- 1.1 If intact abort (CONT = OFF) and ISTEP4 = 0, then execute Equation Set 1.2; otherwise, execute Equation Set 1.3.A.
- 1.2 If EOW < EST, then (ISTEP4 = 1 and DPSAC_INIT = OFF.)
- 1.3.A If intact abort (CONT = OFF) and EOW > ES and MACH < MSW3 and PSHA < PSSTRN, then execute Equation Set 1.3.1, skip Equation Set 1.3.2, then proceed to Equations 1.4 and 1.5; else, proceed to Equations 1.4 and 1.5.
- 1.3.B If ECAL = ON and (EOW > ES or ISTEP4 = 0), then execute Equation Sets 1.3.1 and 1.3.2 then proceed to 3.3 and continue; else, proceed to Equation Set 3 and continue.
 - 1.3.1.1 ISTEP4 = 0
 - 1.3.1.2 $S = -YSGN$

- 1.3.1.3 $SPSI = S \text{ RES180}(PSD)$
- 1.3.1.4 If $SPSI < 0$ and $PSHA < 90.0$, then $S = -S$
- 1.3.2.1 If $DPSAC_INIT = OFF$, then execute Equations 1.3.2.1.1 and 1.3.2.1.2
 - 1.3.2.1.1 $DPSACI = DPSAC$
 - 1.3.2.1.2 $DPSAC_INIT = ON$
- 1.3.2.2 $PHIC = PHIC_AT = PHISTN \text{ SIGN}(DPSACI)$
- 1.3.2.3 $DPSACLMT = \text{MIN}(DPHISLP \text{ MACH} + DPHIINT, DPSACLMT_MAX)$
- 1.3.2.4 $DPSACT = -DPSACLMT \text{ SIGN}(DPSACI)$
- 1.3.2.5 If $DPSACT \geq 0.$, then execute Equation 1.3.2.5.1 and skip Equation 1.3.2.5.2. Otherwise, execute Equation Set 1.3.2.5.2.
 - 1.3.2.5.1 If $DPSAC \geq DPSACT$, then $DPSAC_INIT = OFF$
 - 1.3.2.5.2 If $DPSAC \leq DPSACT$, then $DPSAC_INIT = OFF$
- 1.4 If $ISTP4 = 0$, then $PHIC = S \text{ PHILIM}$; otherwise, $PHIC = GPHI \text{ DPSAC}$
- 1.5 $PHIC_AT = \text{MIDVAL}(PHIC, -PHILIM, PHILIM)$

- 2.1 $PHIC = 0.0$
- 2.2 $PHIC_AT = PHIC$
- 2.3 If $(CONT = ON)$, execute Equations 3.1 and 3.3, then exit the function. (Eqns 3.1 and 3.3 are executed in case an ECAL abort is later performed.)

- 3.1 If $HDOT > HDTBNK$ and $ACC_VERT > 0.0$ and $IPHASE \neq 6$, then $IBNK = ON$.
- 3.2 If $IBNK = ON$, then $PHIC = \text{DELFACT} \text{ DPSAC}$ and $PHIC_AT = \text{MIDVAL}(PHIC, -PHISS, PHISS)$.
- 3.3 If $IPHASE = 4$ and $HDOT < HDRLPT$ and $ACC_VERT < 0.0$, then $IRLPTF = ON$.
- 3.4 If $IBNK = ON$ and $IRLPTF = ON$, then execute Equation set 3.4.1.
 - 3.4.1.1 $PHIGN = PHIC_AT (1 + (HDOT + HDOTBS) / HDBIAS + ACC_VERT / VABIAS)$.
 - 3.4.1.2 $PHIC_AT = \text{MIDVAL}(PHIC_AT, PHIGN, -PHIGN)$.

- 3.4.1.3 $PHINZ2 = [ARCCOS(MIDVAL((COSTH / MAX(DNZMX2 - ABS(NZ), 0.01)), 1.0, -1.0))] DEG_PER_RAD.$
- 3.4.1.4 If $ABS(PHIC_AT) > ABS(PHINZ2)$, then
 $PHIC_AT = PHINZ2 SIGN(PHIC_AT).$
- 3.5 If $IBNK = OFF$ and $ITGTNZ = OFF$, then $PHIC = PHIC_AT = 0.$
- 3.6 If $IBNK = OFF$ and $ITGTNZ = ON$, then $PHIC = PHIC_AT = PHIPRB SIGN(DPSAC).$

B. Interface Requirements. The input/output parameters for GRPHIC are listed in Table 4.8.2.12-1. The I-loads/constants are listed in Table 4.8.2.12-2.

C. Processing Requirements. GRPHIC is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. ISTEP4 is initialized in GRINIT.

E. Supplemental Information. The following function is called by GRPHIC: RES180.

Table 4.8.2.12-1. GRPHIC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
IPHASE	TAEM phase counter	GRINIT, GRTRN	ND	I
PSHA	HAC turn angle	GTP	deg	F
MACH	Mach number	ADTA SOP	ND	F
DPSAC	Heading error to the HAC tangency point	GTP	deg	F
PHILIM	Phase dependent roll command limit	GRINIT	deg	F
PSD	Heading wrt runway centerline	RTLS UPP	deg	F
EOW	Energy over weight	TGCOMP	ft	F
ES	Energy over weight reference for S–turn initiation	TGCOMP	ft	F
EST	Energy over weight reference for S–turn termination	TGCOMP	ft	F
ISTP4	Phase 4 S–turn flag	GRINIT	ND	I
YSGN	Sign of Y	RTLS UPP	ND	F
CONT	RTLS contingency flag	PW RTLS GUID, PW CONT GUID, MSC, GRTRN, CONT 3 E/O GUID	ND	D
ECAL	ECAL logic ena/inh discrete	VERT SIT 1, GRINIT, GRTRN	ND	D
ITGTNZ	ECAL prebank initiation flag	GRALPC	ND	D
ACC_VERT	Vertical acceleration	RTLS UPP	ft/s ²	F
COSTH	Euler angle pitch cosine	A/E ATT PROC	ND	F
HDOT	Estimated altitude rate	RTLS UPP	ft/s	F
NZ	Normal acceleration feedback	SF	g	F
DPSAC_INIT	ECAL high energy heading error init flag	GRINIT	ND	D
OUTPUTS				
PHIC_AT	Commanded roll angle	AEROJET DAP, E/L ADI PROC, TLM	deg	F
PHIC	Unlimited roll command	TGTRAN, TLM	deg	F
ISTP4	Phase 4 S–turn flag	GRTRN	ND	I
S	Sign of roll command for the S–turn	TGPHIC, TLM	ND	F
IBNK	ECAL roll logic flag	TLM	ND	D
IRLPTF	ECAL roll protection flag	TLM	ND	D

Table 4.8.2.12-2. GRPHIC I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0246C	GPHI	Acquisition roll command gain on DPSAC		ND	SX
V96U1897C	MSW3	Mach switch for allowing S-turns in Phase 4		ND	MX
V96U8651C	PSSTRN	Maximum PSHA for S-turn		deg	SX
V99U6530C	HDTBNK	Roll initiation altitude rate for phase 5 ECAL logic		ft/s	MX
V99U6511C	DELFAC	Roll command gain on DPSAC for ECAL roll commands		ND	MX
V99U6533C	PHISS	Maximum ECAL roll limit		deg	MX
V99U6559C	PHISTN	ECAL S-turn roll limit		deg	MX
V99U6529C	HDRLPT	Altitude rate to start ECAL roll protection in phase 4		ft/s	MX
V99U6528C	HDOTBS	Altitude rate bias term used in QBAR roll protection logic for ECAL		ft/s	MX
V99U6509C	HDBIAS	Altitude rate bias term used in QBAR roll protection logic for ECAL		ft/s	MX
V99U6510C	VABIAS	Altitude acceleration bias term used in QBAR roll protection logic for ECAL		ft/s ²	MX
V99U6513C	DNZMX2	Maximum Nz limit for Nz roll protection logic for ECAL		g	MX
V99U6532C	PHIPRB	ECAL prebank roll command		deg	MX
V97U0112C	DEG_PER_RAD	Radian-to-Degree Conversion Factor	57.2957795131	deg/rad	X
V97U3699C	DPHISLP	Slope of DPSACLMT with MACH		deg	MX
V97U3700C	DPHIINT	Constant used to compute DPSACLMT		deg	MX
V97U3701C	DPSACLMT_MAX	Maximum value of DPSACLMT		deg	MX

4.8.2.13 Phase Transition, MEP, and OHALRT Function (TGTRAN).

This module determines TAEM phase transitions for phases 0, 1, 2, and 3 and performs any initialization required due to a phase transition. Also, this function checks for a minimum entry point (MEP) situation and sends out the MEPALERT flag to DI if required. An Overhead HAC low energy situation is also checked and if true, the TAEM guidance downmoding flag, OHALRT, is sent to DI to flash Item 6 on the HSD and to issue a Class 3 alarm. S–turn (IPHASE = 0) initiation and termination, as well as the MEP and OHALRT checks, are based on energy over weight errors. If $EOW > EN$, the vehicle is high in energy; and if $EOW < EN$, the vehicle is low in energy.

This function normally will be entered in the acquisition phase (IPHASE = 1). In the normal situation, the orbiter will remain in this phase until the heading alignment phase is initiated. However, if the energy state is too high, the S–turn phase will be initiated unless the predicted range is less than the minimum range allowed for an S–turn (RMINST) or the HAC turn angle, PSHA, is greater than a predetermined value, PSSTRN. The main objective of the S–turn is to rotate heading so that a longer ground path can be covered without getting into a geometry problem with respect to the HAC. This geometry problem exists only for HAC turn angles ≤ 135 degrees, but the capability for doing S–turns even with the Overhead HAC is possible through proper selection of the value of PSSTRN. The direction in which the S–turn is made depends on which side of the runway centerline the HAC is located and on the orbiter heading. The logic for selection of the turn direction is as follows:

$$S = -Y_{SGN}$$

$$\text{If } S \psi_{RW} < 0 \text{ and } \psi_{HA} < 90, \text{ then } S = -S$$

where

$$S = -1 = \text{left bank}$$

$$S = +1 = \text{right bank}$$

Termination of the S–turn occurs when the energy drops below the S–turn termination level; i.e., $EOW < EST$.

During the acquisition phase, the MEPALERT flag will be issued whenever EOW becomes less than the MEP value for EOW (EMEP) and the NEP flag is TRUE. Transition to the heading alignment phase from the acquisition phase occurs whenever $RCIR < (P2TRNC1 - RTURN)$, where RCIR is the orbiter's radial distance from the HAC center and RTURN is the HAC radius.

Transition to the prefinal phase (IPHASE = 3) occurs whenever the predicted range is less than the prefinal initiation range value (RPRED3), or if the altitude is less than a predetermined value (H_MIN_3).

After phase 3 is initiated, the TAEM–to–Approach/Land transition logic is executed to determine when the transition to A/L will take place.

Deviations from the normal functional operations of TGTRAN involve those processing requirements necessary to support a bailout abort. If a bailout abort is desired (via an ATO abort request subject to major mode and velocity constraints), a BAILOUT_ARM flag is set and latched. This flag will be used to prevent transition to A/L and will provide feedback to the crew for confirmation of the bailout request. FCS CSS/Auto command axis moding is then monitored to establish the state of the BAILOUT_BANK AND BAILOUT_PITCH flags as used to configure the guidance for bailout roll and pitch command operations.

A. Detailed Requirements. Upon entering TGTRAN, the bailout request flag is checked, and if TRUE, the BAILOUT_ARM flag is set to TRUE and latched as shown in Equation 0.1.

$$0.1 \quad \text{If (BAILOUT_FLAG = ON), then BAILOUT_ARM = ON}$$

The BAILOUT_BANK or BAILOUT_PITCH discrete is set to ON once the BAILOUT_ARM discrete is ON and whenever the appropriate FCS command channel axis is moded from CSS to auto as shown in Equations 0.2 and 0.3.

$$0.2 \quad \text{If (BAILOUT_ARM = ON and AUTORY_LAMP = ON and AUTORY_LAMP_PAST = OFF), then BAILOUT_BANK = ON}$$

$$0.3 \quad \text{If (BAILOUT_ARM = ON and AUTOP_LAMP = ON and AUTOP_LAMP_PAST = OFF), then BAILOUT_PITCH = ON}$$

Past values for the FCS command axis moding discretely are saved as shown in Equations 0.4 and 0.5.

$$0.4 \quad \text{AUTORY_LAMP_PAST = AUTORY_LAMP}$$

$$0.5 \quad \text{AUTOP_LAMP_PAST = AUTOP_LAMP}$$

Whenever an FCS command axis is being operated in a CSS mode condition, the corresponding bailout bank or pitch discrete is set to FALSE as shown in Equations 0.6 and 0.7.

$$0.6 \quad \text{If (AUTORY_LAMP = OFF), then BAILOUT_BANK = OFF}$$

$$0.7 \quad \text{If (AUTOP_LAMP = OFF), then BAILOUT_PITCH = OFF}$$

If IPHASE = 3, a logical test is made for termination of TAEM guidance as per the following:

$$\text{If } ((\text{ABS}(\text{HERROR}) < (\text{H_DEL_H1} - \text{DEL_H2}))$$

and

$$(\text{ABS}(\text{Y}) < (\text{H_Y_RANGE1} - \text{Y_RANGE2}))$$

and

$$(\text{ABS}(\text{GAMMA} - \text{GAMSGS}_1) < (\text{H_GAMMA_COEF1} - \text{GAMMA_COEF2}))$$

and

$$(\text{ABS}(\text{QBERR}) < \text{QB_ERROR2})$$

and

$$(\text{H_REF1} > \text{H})$$

or $(\text{H} < (\text{H_REF2}))$ and $(\text{BAILOUT_ARM} = \text{OFF})$

then the TAEM guidance termination flag is set to TRUE; i.e., $\text{TG_END} = \text{ON}$. The TGTRAN function then is exited. Otherwise ($\text{IPHASE} \neq 3$), a test for transition to the prefinal phase ($\text{IPHASE} = 3$) is made on the basis of whether the predicted range is less than the prefinal initiation range value ($\text{RPRED} < \text{RPRED3}$), or if altitude is less than the minimum prefinal initiation value ($\text{H} < \text{H_MIN_3}$). If either is true, Equation Set 1 is executed:

- 1.1 $\text{IPHASE} = 3$
- 1.2 $\text{PHIO} = \text{PHIC}$
- 1.3 $\text{PHILIM} = \text{PHILM3}$
- 1.4 $\text{DNZUL} = \text{DNZUC2}$
- 1.5 $\text{DNZLL} = \text{DNZLC2}$

If the prefinal initiation test is false (i.e., $\text{RPRED} \geq \text{RPRED3}$ and $\text{H} \geq \text{H_MIN_3}$), the appropriate logic based on the current TAEM phase is executed as follows:

For $\text{IPHASE} = 0$ (S–turn):

If the current energy over weight is less than the S–turn termination energy over weight ($\text{EOW} < \text{EST}$), then Equation Set 2 is executed.

- 2.1 $\text{IPHASE} = 1$
- 2.2 $\text{PHILIM} = \text{PHILM1}$

For $\text{IPHASE} = 1$ (acquisition):

1. First the test to initiate an S–turn is made on the basis of passing the following criteria:

$$\text{EOW} > \text{ES} \text{ and } \text{DRPRED} > \text{RMINST}_1 \text{ and } \text{PSHA} < \text{PSSTRN}.$$

If this test is passed (true), Equation Set 3.1 is executed:

- 3.1.1 $\text{IPHASE} = 0$
- 3.1.2 $\text{PHILIM} = \text{PHILM0}$
- 3.1.3 $\text{S} = -\text{YSGN}$
- 3.1.4 $\text{SPSI} = \text{S RES180}(\text{PSD})$
- 3.1.5 If $\text{SPSI} < 0$ and $\text{PSHA} < 90.0$, then $\text{S} = -\text{S}$

2. Next, the tests for determining MEP and OHALRT situations are made. The criteria for issuing a MEPALERT discrete are based on passing the following test:

$$EOW < EMEP \text{ and } NEP = ON$$

If this test is true, then the MEP alert discrete is set to true (MEPALERT = ON); otherwise, the MEP alert discrete is set to false (MEPALERT = OFF).

Next, the test for determining an OHALRT situation is made as follows:

If (EOW < EMOH and PSHA > PSOHAL and RPRED > RMOH)

then OHALRT = ON; otherwise OHALRT = OFF

3. The test for transition to the heading alignment phase (IPHASE = 2) is now made. If RCIR < P2TRNC1 RTURN is satisfied, Equation Set 3.3 is executed.

3.3.1 IPHASE = 2

3.3.2 PHILIM = PHILM2

For IPHASE = 2 (heading alignment), no additional computations are presently required.

B. Interface Requirements. The input/output parameters for TGTRAN are listed in Table 4.8.2.13-1. The I-loads/constants are listed in Table 4.8.2.13-2.

C. Processing Requirements. TGTRAN is executed at the RTLS TAEM guidance rate.

D. Initialization Requirements. IPHASE is initialized in GRINIT. The BAILOUT_ARM, BAILOUT_PITCH, and BAILOUT_BANK flags are initialized to OFF prior to first pass through GRTLS TAEM guidance.

E. Supplemental Information. The following function is called by TGTRAN: RES180.

Table 4.8.2.13-1. TGTRAN Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
RPRED	Predicted ground track range to the runway threshold	GTP	ft	F
RPRED3	Prefinal range initiation value	TGXHAC	ft	F
PHIC	Unlimited roll command	TGPHIC, GRPHIC	deg	F
IPHASE	TAEM phase counter	GRINIT, GRTRN	ND	I
NEP	Nominal Entry Point flag	HORIZ SIT DISP	ND	D
QBERR	Current dynamic pressure error	TGCOMP	psf	F
YSGN	Sign of X cross range position wrt runway of selected HAC	GTP	ND	F
PSD	Heading with respect to runway centerline	NAV	deg	F
RCIR	Radial distance from center of closest HAC	GTP	ft	F
HERROR	Altitude error	TGCOMP	ft	F
Y	Cross range position with respect to runway	NAV	ft	F
GAMMA	Ground relative flight path angle	NAV	deg	F
H	Altitude of wheels above runway	NAV	ft	F
EOW	Energy over weight	GRINIT	ft	F
ES	Energy over weight reference for S–turn initiation	TGCOMP	ft	F
EST	Energy over weight reference for S–turn termination	TGCOMP	ft	F
EMEP	Energy over weight reference for MEP alert	TGCOMP	ft	F
DRPRED	RPRED + XALI	TGCOMP	ft	F
PSHA	HAC turn angle	GTP	deg	F
RTURN	Spiral turn radius	GTP	ft	F
EMOH	Energy over weight reference for OHALRT	TGCOMP	ft	F
BAILOUT_FLAG	Bailout request flag	MSC	ND	D
AUTOP_LAMP	Auto lamp status pitch axis	GRTLS DAP	ND	D
AUTORY_LAMP	Auto lamp status status roll/yaw axis	GTRLS DAP	ND	D
AUTOP_LAMP_PAST	Past value of auto lamp status, pitch axis	GRINIT	ND	D
AUTORY_LAMP_PAST	Past value of auto lamp status, roll/yaw axis	GRINIT	ND	D

Table 4.8.2.13-1. TGTRAN Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
OUTPUTS				
MEPALERT	Energy deficiency flag	GAX	ND	D
IPHASE	TAEM phase counter	TGNZC, TLM, TGSBC, NAV, ASC AREA NAV, GREXEC, GRTLS DAP, HUD PROC, TGPHIC, GTP, SPI PROC, VERT SIT 1 DISP, VERT SIT DIP, HORIZ SIT SPEC, E/L ADI PROC, MEDS FC GNC XFER	ND	I
DNZUL	Upper limit on normal acceleration command	TGNZC	g	F
DNZLL	Lower limit on normal acceleration command	TGNZC	g	F
PHIO	Previous unlimited roll command	TGPHIC	deg	F
PHILIM	TAEM phase dependent roll command limit	TGPHIC	deg	F
S	Sign of roll command for S–turn	TGPHIC, TLM	ND	F
OHALRT	TAEM guidance downmode flag	GAX, HORIZ SIT DISP	ND	D
BAILOUT_ARM	Bailout arm flag	TGSBC, TGPHIC, VERT SIT 1 and 2 DISPs	ND	D
BAILOUT_PITCH	Bailout pitch flag	TGNZC, VERT SIT 1 and 2 DISPs	ND	D
BAILOUT_BANK	Bailout bank flag	TGPHIC, VERT SIT 1 and 2	ND	D
TG_END	TAEM guidance termination flag	MSC, E/L ADI PROC, VERT SIT DIP, HORIZ SIT SPEC, SPI PROC, VERT SIT 2 DISP, TLM, HUD PROC, NAV, MEDS FC GNC XFER	ND	D

Table 4.8.2.13-2. TGTRAN I -Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0387C	RMINST(1)	Minimum range to initiate S–turn phase		ft	MX
V97U0343C	PHILM0	Roll command limit – S–turn		deg	SX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX
V97U0345C	PHILM2	Roll command limit – heading alignment		deg	SX
V97U0346C	PHILM3	Roll command limit – prefinal		deg	SX
V97U0351C	P2TRNC1	Constant used in Phase 2 transition logic		ND	SX
V97U0125C	DNZLC2	Phase 3 NZC lower limit		ND	SX
V97U0127C	DNZUC2	Phase 3 NZC upper limit		ND	SX
V97U0236C	GAMSGS(1)	Autoland steep glide slope flight path angle		deg	MX
V97U0354C	QB_ERROR2	Dynamic pressure error bound		psf	SX
V97U0279C	H_REF1	Altitude reference		ft	SX
V97U0280C	H_REF2	Altitude reference		ft	SX
V97U0113C	DEL_H1	Altitude error coefficient		ND	SX
V97U0114C	DEL_H2	Altitude error coefficient		ft	SX
V97U0462C	Y_RANGE1	Cross range coefficient		ND	SX
V97U0463C	Y_RANGE2	Cross range coefficient		ft	SX
V97U0230C	GAMMA_COEFF1	Flight path error coefficient		deg/ft	SX
V97U0231C	GAMMA_COEFF2	Flight path error coefficient		deg	SX
V96U8305C	H_MIN_3	Minimum altitude for prefinal initiation		ft	SX
V96U8651C	PSSTRN	Maximum PSHA for S–turn		deg	SX
V96U8649C	PSOHAL	Minimum PSHA to issue OHALRT		deg	SX
V96U8672C	RMOH	Minimum RPRED to issue OHALRT		deg	SX

4.8.2.14 Speed Brake Command Function (TGSBC).

This module performs the calculations required to generate the speed brake command to the FCS for RTLS TAEM phases 0, 1, 2, and 3. For $MACH > DSBCM$, $DSBC_AT$ is generated from a MACH dependent schedule, otherwise, the following is applicable: During the S–turn phase ($IPHASE = 0$), the speed brake command is simply $DSBLIM$. For all other phases, the unlimited command is based on a nominal speed brake command ($DSBNOM$), plus proportional terms based on a combination of energy, energy rate, and dynamic pressure errors. A blending function is provided to allow for an altitude dependent, linear transition from effectively only an energy and energy rate closed–loop speedbrake command to solely a dynamic pressure derived command to enable equivalence with A/L speedbrake command operations. Additionally, the derived energy rate error, $EDTERI$, is filtered to remove the 0.25 Hz noise introduced by the navigation in its calculation of drag deceleration, ACC_DRAG . Finally, for all phases, the FCS speed brake command, $DSBC_AT$, is calculated based on the unlimited command and the calculated limits. The calculated speed brake limits are MACH dependent schedules.

A deviation from the normal function of TGSBC is the request for a BAILOUT ABORT. A BAILOUT ABORT being declared will command the speed brake to close.

A. Detailed Requirements. If MACH is greater than $DSBCM$, the speed brake command issued to the FCS, $DSBC_AT$, is generated from $DSBC_AT = MIDVAL(MACHSBS \ MACH + MACHSBI, GRSBL2, GRSBL1)$ and TGSBC is exited. Otherwise, the speed brake command limits are calculated using Equation Set 1.

$$1.1 \quad DSBCLL = MIDVAL(DSBSUP + DSBLLS (MACH - DSBCM), 0, DSBSUP)$$

$$1.2 \quad DSBCUL = MIDVAL(DSBSUP + DSBULS (MACH - DSBCM), DSBSUP, DSBLIM)$$

The TAEM phase is then tested, and if $IPHASE = 0$, Equation Set 2 is executed.

$$2.1 \quad DSBC = DSBLIM$$

Otherwise ($IPHASE \neq 0$), Equation Set 3 is executed.

$$3.1 \quad DSBE = GSBE \ QBERR$$

$$3.2 \quad BLEND = MIDVAL(HGAINSB (H - HBLEND), 0., 1.)$$

$$3.3 \quad EDTERI = V (EN_C2_{1,IEL} - ACC_DRAG / GO)$$

$$3.4 \quad \text{If first pass through Equation Set 3,} \\ \text{then } EDTERO = EDTERI$$

$$3.5 \quad EDTERO = (1. - EDSMGAN) EDTERO + EDSMGAN EDTERI$$

$$3.6 \quad DSBC = DSBNOM + BLEND (EOWSBG (EOW - EN) \\ + EDOTSBG EDTERO) - (1. - BLEND) DSBE$$

Finally, the speed brake command issued to the FCS, $DSBC_AT$, is calculated using Equation Set 4.

$$4.1 \quad \text{If } (BAILOUT_ARM = ON), \text{ then } DSBC = 0.0$$

$$4.2 \quad DSBC_AT = MIDVAL(DSBC, DSBCLL, DSBCUL)$$

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- B. Interface Requirements. The input/output parameters for TGSBC are listed in Table 4.8.2.14-1. The I-loads/constants are listed in Table 4.8.2.14-2.
- C. Processing Requirements. TGSBC is executed at the RTLS TAEM Guidance rate.
- D. Initialization Requirements. None.

Table 4.8.2.14-1. TGSBC Input/Output Parameters				
Name	Description	Source / Destination	Units	Type
INPUTS				
BAILOUT_ARM	Bailout arm flag	TGTRAN	ND	D
MACH	GN&C Mach number	ADTA SOP	ND	F
QBERR	Dynamic pressure error	TGCOMP	psf	F
IPHASE	TAEM phase counter	GRINIT, TGTRAN, GRTRN	ND	I
EOW	Energy over weight	TGCOMP	ft	F
EN	Nominal energy over weight reference	TGCOMP	ft	F
ACC_DRAG	Drag deceleration	NAV	ft/sec ²	F
H	Altitude of wheels above runway	NAV	ft	F
V	Ground relative velocity magnitude	NAV	ft/sec	F
IEL	Energy reference index	TGCOMP	ND	I
OUTPUTS				
DSBC_AT	Commanded speed brake position	GRTLS DAP, SPI PROC, VERT SIT DIP, TLM	deg	F

Table 4.8.2.14-2. TGSBC I-Loads/Constants					
MSID No.	Name	Description	Value	Units	Class
V97U0257C	GSBE	Speed brake proportional gain on QBERR		deg/psf	SX
V97U0134C	DSBNOM	Nominal speed brake command		deg	SX
V96U8664C	DSBLLS	Constant used to compute DSBCLL		deg	SX
V97U0133C	DSBLIM	Maximum value of speed brake command		deg	SX
V96U8665C	DSBULS	Constant used to compute DSBCUL		deg	SX
V97U0131C	DSBCM	MACH at which speed brake modulation begins		ND	SX
V97U0135C	DSBSUP	Maximum supersonic fixed speed brake deflection		deg	SX
V97U0255C	GRSBL1	Maximum allowed value of DSBC_AT		deg	MX
V97U0256C	GRSBL2	Minimum allowed value of DSBC_AT		deg	MX
V96U7785C	MACHSBS	Slope for Mach scheduled speed brake command		deg	MX
V96U7784C	MACHSBI	Constant for Mach scheduled speed brake command		deg	MX
V97U0187C	HBLEND	Altitude for 100% dynamic pressure speedbrake control		ft	SX
V97U0188C	HGAINSB	Blender gain on altitude		ft ⁻¹	SX
V97U0190C	EDSMGAN	Energy rate error filter gain		ND	SX
V97U0192C	EOWSBG	Speedbrake gain on energy error		deg/ft	SX
V97U0194C	EDOTSBG	Speedbrake gain on energy rate error		deg-sec/ft	SX
V97U0181C	EN_C2(1, J)*	Slope of EN with range		ND	MX
V97U0182C					
V97U0183C		*J = 1, 2, 3, 4			
V97U0184C					
V90A7622C	GO	Acceleration of gravity at sea level	32.174049	ft/sec ²	X

4.8.2.15 Roll Command Function (TGPHIC).

The function TGPHIC computes the roll command, PHIC_AT, for the lateral axis command to the FCS for RTLS TAEM phases 0, 1, 2, and 3. If the guidance is in the S–turn phase (IPHASE = 0), a constant roll command equal to S PHILIMIT is issued to the FCS, where S is the sign of the roll command calculated in TGTRAN and PHILIMIT is the maximum roll command allowed. During the acquisition phase (IPHASE = 1), a roll command is given which is proportional to the orbiter’s heading deviation from tangency to the nearest HAC. In the heading alignment phase (IPHASE = 2), the roll command is generated to assure that the orbiter performs a turn which follows the heading alignment cone. In the prefinal phase (IPHASE = 3), the roll command is generated from a linear combination of the orbiter’s lateral deviation and deviation rate from the runway centerline. The roll command limit, PHILIMIT, is a Mach dependent schedule with supersonic, phase dependent, and normal load limit constraints.

Deviations from the normal functional operations of TGPHIC involve those processing requirements necessary to support bailout commands. If the bailout mode has been requested but not engaged in the roll axis (i.e., BAILOUT_ARM = ON and AUTORY_LAMP = OFF), the roll command is simply set to the current roll attitude. Whenever the bailout mode is engaged in the roll axis (e.g., BAILOUT_BANK = ON), the roll command will become fixed and will reflect the value of roll existent at the time of engagement.

A. Detailed Requirements. Upon entering TGPHIC, the roll command limit is calculated using PHILIMIT = MIDVAL(PHILMSUP + PHILS (MACH – PHIM), PHILMSUP, PHILIM); but if the air data system is in a default condition, the supersonic constraint is removed, i.e., if DEF_AD = ON then PHILIMIT = PHILIM. Next, the unlimited roll command, PHIC, is generated on the basis of the current TAEM phase as follows:

1. IPHASE = 0 (S–turn):
 - 1.1 PHIC = S PHILIMIT
2. IPHASE = 1 (acquisition):
 - 2.1 PHIC = GPHI DPSAC
3. IPHASE = 2 (heading alignment):
 - 3.1 RERRC = RCIR – RTURN
 - 3.2 If RERRC > RERRLM, then execute Equation Set 3.3; otherwise, execute Equation Set 3.4.
 - 3.3.1 PHIC = GPHI DPSAC
 - 3.3.2 If PHILIMIT > PHILM1, then PHILIMIT = PHILM1
 - 3.4.1 $RDOT = -(XCIR \cdot XDOT + YCIR \cdot YDOT)/RCIR$
 - 3.4.2 $PHIP2C = (VH^2 - RDOT^2) \text{ DEG_PER_RAD}/(GO \text{ RTURN})$
PHIP2C = PHIP2C (PHI2C1 – PHI2C2 PHIP2C)

- 3.4.3 $RDOTRF = -VH (R1 + 2 R2 PSHA) DEG_PER_RAD/RTURN$
- 3.4.4 $PHIC = YSGN (MAX(SCALAR(0, PHIP2C + GR RERRC + GRDOT (RDOT - RDOTRF))))$
- 4. IPHASE = 3 (prefinal):
 - 4.1 $YERRC = MIDVAL(-GY Y, -YERRLM, YERRLM)$
 - 4.2 $PHIC = YERRC - GYDOT YDOT$
 - 4.3 $PHILIMIT = MIDVAL(PHILM3, PHILM4, PHILR1 (ABS(PHIC) + PHILR2))$
 - 4.4 If $ISR > 0$, then
 - 4.4.1 $DPHI = (PHIC - PHIO)/ISR$
 - 4.4.2 $ISR = ISR - 1$
 - 4.4.3 $PHIC = PHIO + DPHI$
 - 4.4.4 $PHIO = PHIC$

After the required phase dependent roll command calculations are made, the normal load roll angle limit, PHINZ, is computed as shown in Equation 5.1. The Mach and phase dependent roll command limit, PHILIMIT, is then reset to PHINZ if it exceeds the normal load roll angle limit as shown in Equation 5.2.

- 5.1 $PHINZ = ARCCOS(COSTH / (GMAX - NZC)) DEG_PER_RAD$
- 5.2 If $PHILIMIT > PHINZ$, then $PHILIMIT = PHINZ$

Finally, the roll command to the FCS, PHIC_AT, is calculated using Equation Set 6 which includes those specific provisions for bailout roll command processing as previously described.

- 6.1 $PHIC_AT = MIDVAL(PHIC, -PHILIMIT, PHILIMIT)$
- 6.2 If $(BAILOUT_ARM = ON \text{ and } AUTORY_LAMP = OFF)$, then $PHIC_AT = PHI$
- 6.3 If $(BAILOUT_BANK = ON)$, then execute Equations 6.3.1 and 6.3.2.
 - 6.3.1 If $(ISNAPB = OFF)$, then
 - 6.3.1.1 $PHIC_ATS = PHI$
 - 6.3.1.2 $ISNAPB = ON$
 - 6.3.2 $PHIC_AT = PHIC_ATS$

If the bailout engagement test fails (i.e., $BAILOUT_BANK = OFF$), then the ISNAPB discrete is set to OFF.

- B. Interface Requirements. The input/output parameters for TGPHIC are listed in Table 4.8.2.15-1. The I-loads/constants are listed in Table 4.8.2.15-2.
- C. Processing Requirements. TGPHIC is executed at the RTLS TAEM guidance rate.
- D. Initialization Requirements. PHILIM and ISR are initialized in GRINIT and PHIO is initialized in TGTRAN. The ISNAPB flag must be initialized to OFF prior to first pass through TGPHIC.

Table 4.8.2.15-1. TGPHIC Input/Output Parameters				
Name	Description	Source/Destination	Units	Type
INPUTS				
MACH	GN&C Mach number	ADTA SOP	ND	F
IPHASE	TAEM phase counter	GRINIT, TGTRAN, GRTRN	ND	I
BAILOUT_ BANK	Bailout bank flag	TGTRAN	ND	D
XDOT	Downrange velocity with respect to the runway	NAV	ft/sec	F
BAILOUT_ ARM	Bailout arm flag	TGTRAN	ND	D
YDOT	Crossrange velocity with respect to the runway	NAV	ft/sec	F
PSHA	HAC turn angle	GTP	deg	F
Y	Crossrange position with respect to the runway	NAV	ft	F
AUTORY_ LAMP	Auto status lamp for roll/yaw axis	GRTLS DAP	ND	D
VH	Horizontal ground speed	NAV	ft/sec	F
PHILIM	Phase dependent roll command limit	GRINIT, TGTRAN	deg	F
PHI	Body roll attitude Euler angle	A/E ATT PROC	deg	F
RTURN	Spiral turn radius	GTP	ft	F
S	Sign of the roll command for the S-turn	TGTRAN, GRPHIC	ND	F
YSGN	Sign of cross range position	NAV	ND	F
DPSAC	Heading error to the HAC tangency point	GTP	deg	F
XCIR	X distance from the nearest HAC center	GTP	ft	F
YCIR	Y distance from the nearest HAC center	GTP	ft	F
RCIR	Radial distance from the nearest HAC center	GTP	ft	F
ISR	Prefinal roll command fader counter	GRINIT	ND	I
PHIO	Previous unlimited roll command	TGTRAN	deg	F
NZC	Normal acceleration command	TGNZC	g	F
COSTH	Euler angle pitch cosine	A/E ATT PROC	ND	F
DEF_AD	Default air data flag	ADTA SOP	ND	D
OUTPUTS				
PHIC_AT	Commanded roll angle	GRTLS DAP, GRTLS A/L GUID, E/L ADI PROC, TLM	deg	F
PHIC	Unlimited roll command	TGTRAN, TLM	deg	F
RDOT	Radial rate from HAC center	TLM	ft/sec	F
RERRC	HAC radial error	TLM, HORIZ SIT SPEC, E/L ADI PROC	ft	F
YERRC	Roll command component due to lateral error for prefinal	TLM	deg	F

Table 4.8.2.15-2. TGPiHC I-Loads/Constants

MSID No.	Name	Description	Value	Units	Class
V97U0246C	GPHI	Acquisition roll command gain on DPSAC		ND	SX
V97U0247C	GR	Gain on RCIR in computing HA roll angle command		deg/ft	SX
V97U0253C	GRDOT	Gain on dRCIR/dt in computing HA roll angle command		deg– sec/ft	SX
V96U8644C	PHILS	Constant used to calculate PHILMIT		deg	SX
V97U0112C	DEG_PER_RAD	Radians–to–degree conversion factor	57.2957795131	deg/rad	X
V90A7622C	GO	Earth gravitational constant	32.174049	ft/sec ²	X
V96U8263C	R1	Coefficient of spiral		ft/deg	SX
V96U8264C	R2	Coefficient of spiral		ft/deg ²	SX
V96U8674C	PHILM4	Alternate Phase 3 roll command limit		deg	SX
V97U0384C	RERRLM	Limit on RERRC		deg	SX
V97U0464C	YERRLM	Limit on YERRC		deg	SX
V97U0263C	GY	Prefinal roll command gain on Y		deg/ft	SX
V97U0264C	GYDOT	Prefinal roll command gain on YDOT		deg– sec/ft	SX
V97U0347C	PHIM	Mach at which supersonic roll command limit is removed		ND	SX
V97U0342C	PHILMSUP	Supersonic roll command limit		deg	SX
V97U0346C	PHILM3	Roll command limit – prefinal		deg	SX
V99U7406C	PHILR1	Slope for bank ramp limit		ND	SX
V99U7407C	PHILR2	Constant for bank ramp limit		deg	SX
V96U7838C	PHI2C1	Coef ₁ of arctan curve fit		ND	SX
V96U7839C	PHI2C2	Coef ₂ of arctan curve fit		deg ⁻¹	SX
V97U0196C	GMAX	Maximum normal load limit		g	MX
V97U0344C	PHILM1	Roll command limit – acquisition		deg	SX

4.8.2.16 Resolve to 180 Degrees (RES180) Function.

The function of RES180 is to resolve the input angle to lie within the range ± 180 degrees.

A. Detailed Requirements. Calling RES180 with the statement $ANG = RES180 (ANG)$ causes the function RES180 to execute the logic shown in Figure 4.8.2.16-1.

B. Interface Requirements. The input/output parameters for RES180 are listed in Table 4.8.2.16-1. There are no I-loads/constants for RES180.

C. Processing Requirements. This module is processed when called.

D. Initialization Requirements. None.

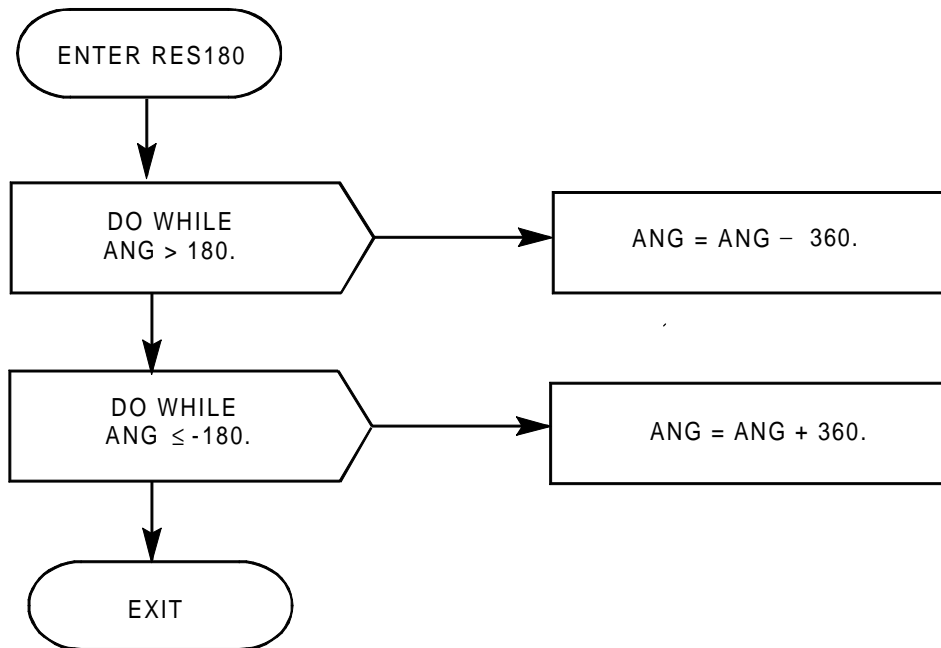


FIGURE 4.8.2.16-1. Resolve to 180 Degrees (RES 180)

Table 4.8.2.16-1. RES180 Input/Output Parameters					
Name	Description	Source/Destination	Type	Units	Sample Rate (Hz)
INPUTS					
ANG	Angle to be resolved	Argument list	F	deg	TAEM guidance rate
OUTPUTS					
ANG	Resolved angle	Function	F	deg	

4.8.3 Parameter Tables for GRTLS TAEM Guidance (G4.204)

The IDD inputs and outputs are listed in Tables 4.8.3-1 and 4.8.3-2 respectively. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.8.3-3. K-loads are listed in Table 4.8.3-4. Constants are listed in Table 4.8.3-5.

TABLE 4.8.3-1. INPUT FUNCTIONAL PARAMETERS FOR GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ACC_DRAG	V95A0160CA	DRAG DECEL	RTLS UPP				89979F	
ACC_VERT	V95A0170CA	VERTICAL ACCEL IN TOPODETTIC COORD	RTLS UPP				90724D	
ALPHA	V95H3021C	GN&C ANGLE OF ATTACK	ADTA SOP	DEG	SPL		93017G	*
ALT_WHEELS	V95H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	RTLS UPP	FT			93017G	*
AUTOP_IND/AUTOP_LAMP	V90X1632XB	PITCH AUTO FLAG	GRTLS DAP				92522D	
AUTORY_IND/AUTORY_LAMP	V90X1642XB	ROLL/YAW AUTO FLAG	GRTLS DAP				92522D	
BAILOUT_FLAG	V90X8654X	BAILOUT FLAG	MSC				89599C	
COSPFI	V90H2204C	EULER ANGLE ROLL COSINE	A/E ATT PROC					
COSTH	V90H2215C	EULER ANGLE PITCH COSINE	A/E ATT PROC				93090E	
COURSE_WRT_RW/PSD	V95H0225CD	COURSE WRT RW CENTERLINE	RTLS UPP	DEG			93017G	*
DEF_AD	V95X3148X	DEFAULT AIR DATA FLAG	ADTA SOP		BD		93017G	*
DSBOFB	V95H8260C	COMP SPDBK POS	SB PFB SOP	DEG			93087E	
ECAL	V93X0255XB	ECAL LOGIC ENA/INH DISCRETE	VERT SIT1 DISP		BD		93090E	
ENT_PT_SW/NEP	V93X4466X	ENTRY POINT SWITCH CMD	HORIZ SIT DISP		BD		89250B	
FLT_PATH_ANG/GAMMA	V95H0261CC	GROUND-REL FLT PATH ANGLE	RTLS UPP	SPECIAL			93017G	*
GI_CHANGE	V93X4476X	HEAD WIND HI/LO CMD	HORIZ SIT DISP		BD		93017G	*
GLIDE_RTLS_INHIBIT	V90X2090XA	RTLS CONTINGENCY FLAG	PW RTLS GUID		BD		93017G	*
GLIDE_RTLS_INHIBIT	V90X2090XB	RTLS CONTINGENCY FLAG	MSC		BD		93090E	
GLIDE_RTLS_INHIBIT	V90X2090XC	RTLS CONTINGENCY FLAG	PW CONT GUID		BD		93017G	*
GLIDE_RTLS_INHIBIT	V90X2090XD	RTLS CONTINGENCY FLAG	CONT 3E/O GUID		BD		93017G	*
GRNZC1	V97U0254C	DESIRED NORMAL ACCEL FOR NZ HOLD	UL	G			92392C	
H_DOT_ELLIPSOID/H_DOT	V95L0265CA	EST ALTITUDE RATE	RTLS UPP	FT/S	SPL		93017G	*
LOAD_TOTAL	V95U0163CC	TOTAL LOAD FACTOR	RTLS UPP				93017G	*
M/MACH	V95L3029C	GN&C MACH NUMBER	ADTA SOP		SPL		93017G	*
MM_CODE_603/MM_603	V90X8122X	MAJOR MODE 603 FLAG	MSC				92355B	
NZ	V90A5381C	SELECTED AA NORMAL ACCEL	SF	G	SPL		93017G	*
NZSW1	V97U0324C	INITIAL VALUE OF NZSW	UL	G			92364D	
PHI/PHI_TOPO	V90H2202C	BODY ROLL ATTITUDE EULER ANGLE	A/E ATT PROC	DEG	SPL		93017G	*
POSN_WRT_RW(1)/X	V95H0220CA	DOWNRANGE DISTANCE WRT RW	RTLS UPP	FT			93017G	*
POSN_WRT_RW(2)/Y	V95H0221CA	CROSSRANGE DISTANCE WRT RW	RTLS UPP	FT			93017G	*
PSHA	V95H0181CB	TURN ANG HAC	RTLS UPP	DEG	SPL		93017G	*
QBAR/QBAR_AD	V95P3011C	GN&C DYNAMIC PRESSURE	ADTA SOP	LBF/FT2	SPL		93017G	*
QBAR_N	V95P3170C	NAV DERIVED DYNAMIC PRESSURE	NAVDAD SOP	LB/FT2	SPL		93017G	*
Q_ORB/Q	V90R5321CA	SELECTED RGA PITCH RATE	SF	DEG/S			93017G	*
REL_VEL_MAG	V95L0151CA	GND REL VEL MAGNITUDE IN M50 SYS	RTLS UPP	FT/S	SPL		93017G	*
RW_ID_UPP/RW_ID	V95U0205CA	INDEX OF CURRENT RW USED FOR UPP	RTLS UPP				90996G	
R_NEP/RTURN	V95U0183CB	HAC RADIUS	RTLS UPP	FT			89250B	
S_CONT_YAW	V99X6557X	CONTINGENCY YAW STEERING DISCRETE	PW CONT GUID		BD		90724D	
TAS	V95L3015C	GN&C TRUE AIRSPEED	ADTA SOP	FT/S	SPL		93017G	*
VEL_WRT_RW(1)/XDOT	V95L0255CB	DOWNRANGE VEL WRT RW	RTLS UPP	FT/S			89250B	
VEL_WRT_RW(2)/YDOT	V95L0256CC	CROSSRANGE VEL WRT RW	RTLS UPP	FT/S			89250B	
V_GROUNDSPEED/VH	V95L0178CA	GROUNDSPEED	RTLS UPP	FT/S			92389C	
YSGNP/YSGN	V95J0153CC	R/L CONE IND PRI RW	RTLS UPP		SPL		93017G	*

TABLE 4.8.3-1. INPUT FUNCTIONAL PARAMETERS FOR GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
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NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.8.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ALPCMD	V90H0803CB	COMMANDED ANGLE OF ATTACK	DL FMT 21/1 GRTLS DAP	DEG			93017G	*
BAILOUT_ARM	V90X1141XB	BAILOUT ARM FLAG	VERT SIT1 DISP VERT SIT2 DISP				89250B	
BAILOUT_BANK	V90X1147XB	BAILOUT BANK FLAG	VERT SIT1 DISP VERT SIT2 DISP				89250B	
BAILOUT_PITCH	V90X1145XB	BAILOUT PITCH FLAG	VERT SIT1 DISP VERT SIT2 DISP				89250B	
DGRNZT	V90U1224C	GUID NZ PULL OUT CMD	MEDS FC GNC XFER TLM VERT SIT1 DISP VERT SIT2 DISP	G			92522D	
DHDRRF DPSAC	V90H1110CB V90H1111CB	TANGENT OF REF FLIGHT PATH ANGLE HDG ERROR FROM TANGENCY WITH HAC	TLM DL FMT 21/1 E/L ADI PROC ENT BRG SPEC	DEG			93017G	*
DSBC_AT	V90H1011CA	SPEEDBRAKE ANGLE COMMAND-AUTO LAND	DL FMT 21/1 GRTLS DAP SPI PROC VERT SIT DIP TLM	DEG			93017G	*
EAS_CMD ECAL	V90L1104CB V93X0255XA	GUID COMMANDED EAS ECAL LOGIC ENA/INH DISCRETE	DL FMT 21/1 ENT BRG SPEC VERT SIT1 DISP	KT	BD		92454A 93017G	*
EMAX	V90U1229CB	UPPER E/W REF FOR NZC LIMITING	VERT SIT DIP	FT				
EMEP	V90U1227CB	E/W REF FOR MEPALERT	VERT SIT DIP	FT				
EMIN	V90U1228CB	LOWER E/W REF FOR NZC LIMITING	VERT SIT DIP	FT				
EMOH	V90U1232CB	E/W REF FOR OHALRT	VERT SIT DIP	FT				
EN	V90U1225CB	REFERENCE ENERGY OVER WEIGHT	VERT SIT DIP	FT				
EN_DELTA	V99U6536C	DELTA TO NOMINAL ENERGY	DL FMT 21/1	FT	SPL		93017G	*
EOW	V90U1231CB	ENERGY OVER WEIGHT	ENT BRG SPEC VERT SIT DIP	FT			93090E	
EOWNZLL	V90A1113CB	ENERGY LOWER LIMIT-NORM ACCEL CMD	TLM	G				
EOWNZUL	V90A1114CB	ENERGY UPPER LIMIT-NORM ACCEL CMD	TLM	G				
ES	V90U1226CB	E/W REF FOR S-TURN INITIATION	VERT SIT DIP	FT				
GLIDE_RTLS_INHIBIT	V90X2090XE	RTLS CONTINGENCY FLAG	ADTA SOP DL FMT 21/1 ENT BRG SPEC GRTLS DAP MEDS FC GNC XFER MSC VERT SIT1 DISP		BD		93017G	*
HERROR	V90H1115CB	ALTITUDE ERROR	E/L ADI PROC HORIZ SIT SPEC HUD PROC TLM	FT			90960E	

TABLE 4.8.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
HREF	V90H1116CB	REFERENCE ALTITUDE	TLM	FT				
IBNK	V99X6538X	ECAL ROLL LOGIC FLAG	DL FMT 21/1		BD		93017G	*
IGI	V90J1047CC	GROUND INTERCEPT INDEX	HUD PROC	FT				
IPHASE	V90J1117CB	TAEM GUIDANCE PHASE INDICATOR	ASC AREA NAV	ND			93017G	*
			DL FMT 21/A					
			E/L ADI PROC					
			ENT BRG SPEC					
			GRTLS DAP					
			HORIZ SIT SPEC					
			HUD PROC					
			MEDS FC GNC XFER					
			RTLS UPP					
			SPI PROC					
			VERT SIT DIP					
			VERT SIT1 DISP					
IPRPTF	V99X6535X	ECAL PITCH PROTECTION FLAG	DL FMT 21/1		BD		93017G	*
IRLPTF	V99X6539X	ECAL ROLL PROTECTION FLAG	DL FMT 21/1		BD		93017G	*
ITGTNZ	V99X6537X	ECAL PREBANK INITIATION FLAG	DL FMT 21/1		BD		93017G	*
MEDS_DPSAC	V90H3907CB	MEDS DISPLAY HEADING ERROR	MEDS FC GNC XFER	DEG	SPL		92522D	
MEPALERT	V90X1105XB	MEP ALERT STATUS	DL FMT 21/A				93017G	*
			GAX					
NEP_FB	V90X1109XA	NEP/MEP FLAG	DL FMT 21/A				93017G	*
			E/L ADI PROC					
			HORIZ SIT SPEC					
			HUD PROC					
NZC	V90A1025CD	NORMAL ACCEL CMD	DL FMT 21/A	G			93017G	*
			GRTLS DAP					
OHALERT	V90X1131XB	TAEM GUID DOWNMODE FLAG	GAX				90881A	
			HORIZ SIT DISP					
PHAVG	V90H1118CB	AVG ROLL ANGLE DURING ACQ TURN	TLM	DEG				
PHIC_AT	V90H1044CE	COMMANDED ROLL ANGLE	DL FMT 21/A	DEG			93017G	*
			E/L ADI PROC					
			GRTLS A/L GUID					
			GRTLS DAP					
PHIC_UL	V90H1031CA	UNLIMITED ROLL COMMAND	TLM	DEG				
QBD	V90P1119CB	FILTERED DYNAMIC PRESSURE RATE	TLM	LB/FT2/S			90185A	
QBERR	V90P1120CB	DYNAMIC PRESSURE ERROR	DL FMT 21/1	LB			93017G	*
QBMNNZ	V90P1121CB	LOWER LIMIT ON DYNAMIC PRESSURE	TLM	LB/FT2				
QBMXNZ	V90P1122CB	UPPER LIMIT ON DYNAMIC PRESSURE	TLM	LB/FT2				
QBNZLL	V90P1124CB	DYNMC PRESS LWR LMT-NORM ACCEL CMD	TLM	G				
QBNZUL	V90P1125CB	DYNMC PRESS UPR LMT-NORM ACCEL CMD	TLM	G				
QBREF	V90P1126CB	DYNAMIC PRESSURE REFERENCE	TLM	LB/FT2				
RDOT	V90R1127CB	RADIAL RATE DEVIATION FROM HAC	TLM	FT/S				
RERRC	V90H1128CB	ROLL CMD COMP-RADIAL ERR FROM HAC	E/L ADI PROC	FT			90960E	
			HORIZ SIT SPEC					
			TLM					

TABLE 4.8.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
RF	V90H1158CB	FINAL TURN RADIUS OF SPIRAL	ASC AREA NAV HORIZ SIT SPEC	FT			92389C	
RPRED	V90H1103CA	RANGE TO RUNWAY THRESHOLD VIA WP1	DL FMT 21/1 ENT BRG SPEC HORIZ SIT SPEC VERT SIT DIP	FT			93017G	*
RTAN	V90H0115CB	STRT LINE DIST TO TANGENCY POINT	E/L ADI PROC HORIZ SIT SPEC	FT			90960E	
RTURN	V90H1159CB	SPIRAL TURN RADIUS	ASC AREA NAV E/L ADI PROC HORIZ SIT SPEC	FT			92389C	
S	V90U1129CB	SIGN OF ROLL COMMAND FOR S-TURN	TLM					
TG_END	V90X1108XB	TAEM GUIDANCE TERMINATION FLAG	E/L ADI PROC GRTLS DAP HORIZ SIT SPEC HUD PROC MEDS FC GNC XFER MSC RTLS UPP RTLS UPP SEQ SPI PROC TLM VERT SIT DIP VERT SIT2 DISP				92355B	
XALI	V94U6518C	TRAJECTORY REFERENCE POINT	ENT BRG SPEC	FT	SPL		93090E	
XHAC	V90U1146CB	X-COORDINATE OF HAC CENTER	ENT BRG SPEC HORIZ SIT SPEC	FT			93090E	
YERRC	V90H1130CB	ROLL CMD COMP DUE TO LATERAL ERROR	TLM	DEG				
	V90M2853PB	CGGB_C13_FLAG1	DL FMT 21/A				93017G	*
	V99M1855PF	CONT MNVR DISCRETES	DL FMT 21/1				93017G	*
	V99M1857P	ECAL LOGIC DOWNLIST PARENT	DL FMT 21/1				93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
ALPC1	V97U0015C	ND	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC10	V97U0016C	ND	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC11	V97U0017C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC12	V97U0018C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC13	V97U0019C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC14	V97U0020C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC15	V97U0021C	ND	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC16	V97U0022C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC17	V97U0023C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC18	V97U0024C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC19	V97U0025C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC2	V97U0026C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC20	V97U0027C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC21	V97U0028C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC22	V97U0029C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC23	V97U0030C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC3	V97U0031C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC4	V97U0032C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC5	V97U0033C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC6	V97U0034C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC7	V97U0035C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC8	V97U0036C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPC9	V97U0037C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPCMDL	V99U9964C	DEG	F	S	D	P	G4.204	00	ZSU	89979F	
ALPE1	V99U9961C	SEC**-1	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPE2	V99U9962C	SEC*G/DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPG1	V97U0038C	SEC**-1	F	S	D	C	G4.204	00	ZSU	89979F	
ALPG2	V97U0039C	SEC*G/DEG	F	S	D	C	G4.204	00	ZSU	89979F	
ALPMACH1	V97U3702C	ND	F	S	M	P	G4.204	00	GEC	92550B	
ALPMACH2	V97U3703C	ND	F	S	M	P	G4.204	00	GEC	92550B	
ALPPRT	V99U6502C	G	F	S	M	P	G4.204	00	GEC	90724D	
ALPQL	V99U9963C	DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ALPREC	V97U0040C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
ALPRECI	V99U5047C	DEG	F	S	M	P	G4.204 G4.6	00	GCA	90705H	
ALPRECL	V99U5049C	DEG	F	S	M	P	G4.204 G4.6	00	GCA	90705H	
ALPRECS	V99U5046C	DEG	F	S	M	P	G4.204 G4.6	00	GCA	90705H	
ALPRECU	V99U5048C	DEG	F	S	M	P	G4.204 G4.6	00	GCA	90705H	
ALP_TRAP_ARM	V97U0041C	DEG	F	S	D	C	G4.204	00	ZSU	93174A	*
ALP_TRAP_TRIG	V97U0094C	DEG	F	S	D	C	G4.204	00	ZSU	93174A	*

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
AMAXI1	V99U6503C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
AMAXLD	V99U7552C	DEG	F	S	M	C	G4.204	00	ZFU	89979F	
AMAXS1	V99U6504C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
AMAXUL	V99U6505C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
AMINI(1)	V99U6506C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINI(2)	V97U3705C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINI(3)	V97U3707C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINS(1)	V99U6507C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINS(2)	V97U3704C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINS(3)	V97U3706C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINUL(1)	V99U6508C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINUL(2)	V97U3708C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
AMINUL(3)	V97U3709C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
CDEQD	V97U0073C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CPMIN	V97U0075C	ND	F	S	D	C	G4.204 G4.9	01 03	ZSU	89979F	
CQDG	V97U0076C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CQG	V97U0077C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
CUBC1(1,1)	V97U0087C	FT	F	S	M	C	G4.204 G4.237 G5.27	00	ZFU	93090E	
CUBC1(1,2)	V97U0088C	FT	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
CUBC2(1,1)	V97U0091C	ND	F	S	M	C	G4.204 G4.237 G5.27	00	XS3	93090E	
CUBC2(1,2)	V97U0092C	ND	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
CUBC3(1,1)	V97U0095C	FT**-1	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
CUBC3(1,2)	V97U0096C	FT**-1	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
CUBC4(1,1)	V97U0099C	FT**-2	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
CUBC4(1,2)	V97U0100C	FT**-2	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
CUBRC(1)	V97U0107C	FT	F	S	M	C	G4.204 G4.237 G5.27	00	GT1	93090E	
DEL1SB	V97U0119C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
DELFAC	V99U6511C	ND	F	S	M	P	G4.204	00	GEC	90724D	
DEL_H1	V97U0113C	ND	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
DEL_H2	V97U0114C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
DEL_R_EMAX(1)	V97U0115C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DHDL1	V99U7435C	G	F	S	D	C	G4.204	00	ZFU	89979F	
DHDNZ	V99U7437C	G*SEC/FT	F	S	M	C	G4.204	00	ZFU	89979F	
DHDUL	V99U7436C	G	F	S	D	C	G4.204	00	ZFU	89979F	
DHOH1	V96U8639C	ND	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DHOH2	V96U8640C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DHOH3	V96U8641C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
DNZ1	V99U6514C	G	F	S	M	P	G4.204	00	GEC	90724D	
DNZB	V99U5050C	G	F	S	M	P	G4.204	00	GCA	DC0762C	
DNZCDL	V97U0122C	G/SEC	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZCG	V97U0123C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZLC1	V97U0124C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZLC2	V97U0125C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DNZMAX	V99U5051C	G	F	S	M	P	G4.204	00	GCA	DC0762C	
DNZMIN	V99U5052C	G	F	S	M	P	G4.204	00	GCA	DC0762C	
DNZMX1	V99U6512C	G	F	S	M	P	G4.204	00	GEC	90724D	
DNZMX2	V99U6513C	G	F	S	M	P	G4.204	00	GEC	90724D	
DNZTHERM	V97U3710C	G	F	S	M	P	G4.204	00	GEC	92550B	
DNZUC1	V97U0126C	G	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
DNZUC2	V97U0127C	G	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DPHIINT	V97U3700C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
DPHISLP	V97U3699C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
DPSAC1	V99U6515C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
DPSAC2	V99U6516C	DEG	F	S	M	P	G4.204	00	GEC	90724D	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
DPSACLMT_MAX	V97U3701C	DEG	F	S	M	P	G4.204	00	GEC	92550B	
DR3	V97U0136C	FT	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
DR4	V96U8635C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	93090E	
DRFK	V96U8663C	ND	F	S	D	X	G5.27 G4.204 G4.9	00	ZSU	93090E	
DSBCM	V97U0131C	ND	F	S	D	C	G4.204 G4.36 G4.9	01 03	ZF8 ZF8	89674E	
DSBLIM	V97U0133C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBLLS	V96U8664C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBNOM	V97U0134C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
DSBSUP	V97U0135C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
DSBULS	V96U8665C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
ECAL_INIT	V99U6517C	ND	D		M	P	G4.204 G6.19	00	GEC	90724D	
ECLRNG1	V99U6540C	FT	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
ECOMPG	V97U0202C	SEC/FT	F	S	D	P	G4.204	00	GEC	93115A	
EDELC1	V97U0142C	ND	F	S	M	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
EDELC2	V97U0143C	ND	F	S	M	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
EDELNZ(1)	V97U0144C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	ZFU ZFU	93090E	
EDOTSBG	V97U0194C	DEG*SEC/FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EDRS(1,1)	V97U0147C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EDRS(1,2)	V97U0148C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EDRS(1,3)	V97U0149C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EDRST(1,1)	V97U0154C	ND	F	S	M	C	G4.204	00	GT1	DC2431A	
EDRST(1,2)	V97U0155C	ND	F	S	M	C	G4.204	00	GT1	DC2431A	
EDRST(1,3)	V97U0156C	ND	F	S	M	C	G4.204	00	GT1	DC2431A	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
EDSMGAN	V97U0190C	ND	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EMEP_C1(1,1)	V97U0161C	FT	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	93090E	
EMEP_C1(1,2)	V97U0162C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EMEP_C1(1,3)	V97U0163C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMEP_C2(1,1)	V97U0167C	ND	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	93090E	
EMEP_C2(1,2)	V97U0168C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EMEP_C2(1,3)	V97U0169C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMEP_ECLI	V99U6547C	FT	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
EMEP_ECLS	V99U6548C	ND	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
EMOHC1(1,1)	V96U8688C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOHC1(1,2)	V96U8689C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOHC1(1,3)	V96U8690C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOHC2(1,1)	V96U8694C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOHC2(1,2)	V96U8695C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOHC2(1,3)	V96U8696C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EMOH_ECLI	V99U6549C	FT	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
EMOH_ECLS	V99U6550C	ND	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
ENALPL	V99U6518C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
ENALPU	V99U6519C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
ENHI_MAX	V99U6552C	FT	F	S	M	P	G4.204	00	GEC	90724D	
ENHI_MIN	V99U6551C	FT	F	S	M	P	G4.204	00	GEC	90724D	
ENLO_MAX	V99U6556C	FT	F	S	M	P	G4.204	00	GEC	90724D	
ENLO_MIN	V99U6555C	FT	F	S	M	P	G4.204	00	GEC	90724D	
EN_BIAS1	V99U6522C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
EN_BIAS2	V99U6523C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
EN_BIAS3	V99U6524C	DEG	F	S	M	P	G4.204	00	GEC	90724D	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
EN_BIAS4	V99U6525C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
EN_C1(1,1)	V97U0173C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C1(1,2)	V97U0174C	FT	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C1(1,3)	V97U0175C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EN_C1(1,4)	V97U0176C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EN_C2(1,1)	V97U0181C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C2(1,2)	V97U0182C	ND	F	S	M	C	G4.204 G4.9 G5.27	01 03	GT1 GT3	93090E	
EN_C2(1,3)	V97U0183C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EN_C2(1,4)	V97U0184C	ND	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EN_ECLI	V99U6541C	FT	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
EN_ECLS	V99U6542C	ND	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
EN_HII	V99U6521C	FT	F	S	M	P	G4.204	00	GEC	90724D	
EN_HIS	V99U6520C	ND	F	S	M	P	G4.204	00	GEC	90724D	
EN_LOI	V99U6554C	FT	F	S	M	P	G4.204	00	GEC	90724D	
EN_LOS	V99U6553C	ND	F	S	M	P	G4.204	00	GEC	90724D	
EOWL2(1)	V97U0211C	FT	F	S	M	C	G4.204	00	ZFU	89979F	
EOWSBG	V97U0192C	DEG/FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
EOW_MP1(1)	V97U0189C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_MP2(1)	V97U0191C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_NP1(1)	V97U0193C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_NP2(1)	V97U0195C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_NP3(1)	V97U0197C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_SP1(1)	V97U0201C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_SP2(1)	V97U0203C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
EOW_STP1(1)	V97U0205C	FT	F	S	M	C	G4.204	00	GT1	DC2431A	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
EOW_STP2(1)	V97U0207C	FT	F	S	M	C	G4.204	00	GT1	DC2431A	
EQLOWL	V96U8671C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
EQLOWU	V96U8642C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
ES1(1,1)	V97U0220C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
ES1(1,2)	V97U0221C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
ES1(1,3)	V97U0222C	FT	F	S	M	C	G4.204 G5.27	00	GT1	93090E	
ESHFMX	V96U8643C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
EST1(1,1)	V97U0213C	FT	F	S	M	C	G4.204	00	GT1	DC2431A	
EST1(1,2)	V97U0214C	FT	F	S	M	C	G4.204	00	GT1	DC2431A	
EST1(1,3)	V97U0215C	FT	F	S	M	C	G4.204	00	GT1	DC2431A	
EST_ECLI	V99U6545C	FT	F	S	M	P	G4.204	00	GEC	90724D	
EST_ECLS	V99U6546C	ND	F	S	M	P	G4.204	00	GEC	90724D	
ES_ECLI	V99U6543C	FT	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
ES_ECLS	V99U6544C	ND	F	S	M	P	G4.204 G5.27	00	GEC	93090E	
GAMMA_COEF1	V97U0230C	DEG/FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
GAMMA_COEF2	V97U0231C	DEG	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
GAMSGS(1)	V97U0236C	DEG	F	S	M	P	G4.204 G4.9	01 03	XS3 XS3	DC0599	
GDHC	V97U0238C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHLL	V97U0239C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHS	V97U0240C	FT**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GDHUL	V97U0241C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEHDL1	V97U0242C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEHDUL	V97U0243C	G*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GELL	V97U0244C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GEUL	V97U0245C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GMAX	V97U0196C	G	F	S	M	C	G4.204	00	GWT	89979F	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
GPHI	V97U0246C	ND	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
GR	V97U0247C	DEG/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GRALL	V99U5053C	DEG	F	S	M	P	G4.204	00	ZSU	89979F	
GRALPI	V97U0249C	DEG	F	S	M	C	G4.204	00	GT1	DC2431A	
GRALPIA	V99U5042C	DEG	F	S	M	P	G4.204	00	GCA	DC0762C	
GRALPL	V97U0250C	DEG	F	S	M	C	G4.204	00	GT1	DC2431A	
GRALPLA	V99U5043C	DEG	F	S	M	P	G4.204	00	GCA	DC0762C	
GRALPS	V97U0251C	DEG	F	S	M	C	G4.204	00	GT1	DC2431A	
GRALPSA	V99U5041C	DEG	F	S	M	P	G4.204	00	GCA	DC0762C	
GRALPU	V97U0252C	DEG	F	S	M	C	G4.204	00	GT1	DC2431A	
GRALPUA	V99U5044C	DEG	F	S	M	P	G4.204	00	GCA	DC0762C	
GRALU	V99U5054C	DEG	F	S	M	P	G4.204	00	ZSU	89979F	
GRALU2	V99U6527C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
GRDOT	V97U0253C	DEG*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GRNZC1	V97U0254C	G	F	S	M	C	G4.204	00	GRM	DC0599	
GRSBL1	V97U0255C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
GRSBL2	V97U0256C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
GSBE	V97U0257C	DEG/(LBS/FT**2)	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GY	V97U0263C	DEG/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
GYDOT	V97U0264C	DEG*SEC/FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
HBLEND	V97U0187C	FT	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	
HDBIAS	V99U6509C	FT/SEC	F	S	M	P	G4.204	00	GEC	90724D	
HDCRLM	V97U0289C	DEG	F	S	D	C	G4.204 G5.27	00	ZSU	93090E	
HDNOM	V99U7438C	FT/SEC	F	S	M	C	G4.204	00	GRM	DC0599	
HDOTBS	V99U6528C	FT/SEC	F	S	M	P	G4.204	00	GEC	90724D	
HDREQG	V97U0290C	SEC**-1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
HDRLPT	V99U6529C	FT/SEC	F	S	M	P	G4.204	00	GEC	90724D	
HDSEB	V99U5056C	FT/SEC	F	S	M	P	G4.204	00	GCA	DC0762C	
HDTBNK	V99U6530C	FT/SEC	F	S	M	P	G4.204	00	GEC	90724D	
HDTRN	V96U7792C	FT/SEC	F	S	M	C	G4.204	00	GT1	DC2431A	
HDTRNA	V99U5045C	FT/SEC	F	S	M	P	G4.204	00	GCA	DC0762C	
HFTC(1)	V97U0291C	FT	F	S	D	C	G4.204 G4.220 G4.237 G4.9	01 03	ZFU ZFU	89979F	
HGAINSB	V97U0188C	FT**-1	F	S	D	C	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
HMEP(1)	V96U8636C	FT	F	S	D	C	G4.204 G4.220 G4.237 G4.9	01 03	ZFU ZFU	89979F	
H_MIN_3	V96U8305C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
H_REF1	V97U0279C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
H_REF2	V97U0280C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
ICNTR_LIM	V99U6531C	ND	I	S	M	P	G4.204	00	GEC	90724D	
MACHSB	V99U5057C	ND	F	S	M	P	G4.204	00	GCA	DC0762C	
MACHSBI	V96U7784C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
MACHSBS	V96U7785C	DEG	F	S	M	C	G4.204	00	ZSU	89979F	
MACHTHERM1	V97U3711C	ND	F	S	M	P	G4.204	00	GEC	92550B	
MACHTHERM2	V97U3713C	ND	F	S	M	P	G4.204	00	GEC	92550B	
MACHTHERM3	V97U3715C	ND	F	S	M	P	G4.204	00	GEC	92550B	
MSW1	V97U0317C	ND	F	S	M	C	G4.204	00	ZSU	89979F	
MSW3	V96U1897C	ND	F	S	M	C	G4.204	00	ZSU	89979F	
NZSW1	V97U0324C	G	F	S	M	C	G4.204	00	GRM	DC0599	
NZTHMBIAS1	V97U3712C	G	F	S	M	P	G4.204	00	GEC	92550B	
NZTHMBIAS2	V97U3714C	G	F	S	M	P	G4.204	00	GEC	92550B	
P2TRNC1	V97U0351C	ND	F	S	D	C	G4.103 G4.204 G4.9 G5.7	00	ZSU	90960E	
PBRCQ(1)	V97U0333C	FT	F	S	M	C	G4.204 G4.9	01 03	GT1 GT3	DC2431A	
PEWRR	V96U8645C	ND	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHAVGC	V97U0335C	DEG	F	S	D	X	G4.204 G4.220 G4.237 G4.9 G5.27	00	ZSU	93090E	
PHAVGLL	V97U0336C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PHAVGS	V97U0337C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
PHAVGUL	V97U0338C	DEG	F	S	D	C	G4.204 G4.220 G4.237 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PHI2C1	V96U7838C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHI2C2	V96U7839C	DEG** -1	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILM0	V97U0343C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM1	V97U0344C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM2	V97U0345C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILM3	V97U0346C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILM4	V96U8674C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILMSUP	V97U0342C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
PHILR1	V99U7406C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILR2	V99U7407C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHILS	V96U8644C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHIM	V97U0347C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PHIPRB	V99U6532C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
PHISS	V99U6533C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
PHISTN	V99U6559C	DEG	F	S	M	P	G4.204	00	GEC	90724D	
PQBWRR	V96U8646C	LB/FT**3	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PSHAO	V96U8687C	DEG	F	S	D	C	G4.204	00	ZSU	89979F	
PSHARS	V96U8647C	DEG	F	S	D	C	G4.19 G4.20 G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27	01 03	ZFU ZFU	93090E	
PSOHAL	V96U8649C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
PSOHQB	V96U8650C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
PSRF	V96U8648C	DEG	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
PSSTRN	V96U8651C	DEG	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBARDL	V97U0355C	LBS/FT**2/SEC	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBC1(1)	V97U0356C	LBS/FT**2/FT	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBC2(1)	V97U0358C	LBS/FT**2/FT	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBG1	V97U0360C	SEC**-1	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBG2C1	V97U0362C	SEC*/G/LBS/FT**2	F	S	D	C	G4.204	00	ZSU	89979F	
QBG2C2	V97U0363C	SEC*/G/LBS/FT**2	F	S	D	C	G4.204	00	ZSU	89979F	
QBG2LL	V97U0364C	SEC*/G/LBS/FT**2	F	S	D	C	G4.204	00	ZSU	89979F	
QBG2UL	V97U0365C	SEC*/G/LBS/FT**2	F	S	D	C	G4.204	00	ZSU	89979F	
QBM1	V97U0371C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBM2	V97U0372C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBMSL1	V96U8654C	LBS/(SLUG*FT**2)	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBMSL2	V96U8655C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBMX1	V97U0367C	LBS/FT**2	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBMX2	V97U0368C	LBS/FT**2	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBMX3	V97U0369C	LBS/FT**2	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBMXS1	V96U8676C	LBS/FT**2	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBMXS2	V97U0366C	LBS/FT**2	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QBREF2(1)	V96U8652C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBRLL(1)	V97U0373C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBRML(1)	V97U0375C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBRUL(1)	V97U0377C	LBS/FT**2	F	S	M	C	G4.204 G4.9	01 03	GT1	DC2431A	
QBWT1	V96U8656C	LBS/(SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
QBWT2	V96U8657C	LBS/ (SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QBWT3	V96U8658C	LBS/ (SLUG*FT**2)	F	S	D	C	G4.204 G4.9	01 03	ZFU	89979F	
QB_ERROR2	V97U0354C	LBS/FT**2	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
QMACH1	V96U8659C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
QMACH2	V96U8660C	ND	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
R1	V96U8263C	FT/DEG	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27	00	ZSU	93090E	
R2	V96U8264C	FT/DEG**2	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27 G5.7	00	ZSU	93090E	
R2MAX	V96U8673C	FT	F	S	D	C	G4.204 G4.9 G5.27	01 03	ZFU	93090E	
RERRLM	V97U0384C	FT	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
RFMN	V96U8661C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
RFMX	V96U8662C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
RFO	V96U8262C	FT	F	S	D	X	G4.204 G4.220 G4.23 G4.237 G4.24 G4.25 G4.9 G5.27 G5.7	00	ZSU	93090E	
RFTC	V97U0385C	SEC	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
RMINST(1)	V97U0387C	FT	F	S	M	C	G4.204 G4.9	01 03	ZFU ZFU	89979F	
RMOH	V96U8672C	FT	F	S	D	X	G4.204 G4.9 G5.27	00	ZSU	93090E	
ROLLRT	V97U0391C	DEG/SEC	F	S	D	C	G4.204 G5.27	00	ZSU	93090E	
RTURNO	V96U8374C	FT	F	S	D	C	G4.204	00	ZSU	93155B	
SBQ	V97U0401C	LBS/FT**2	F	S	D	C	G4.204	00	ZSU	89979F	
SMNZ2L	V97U0408C	G	F	S	M	C	G4.204	00	ZSU	89979F	
SMNZC1	V97U0404C	G	F	S	M	C	G4.204	00	ZSU	89979F	
SMNZC2	V97U0405C	G	F	S	M	C	G4.204	00	ZSU	89979F	
SMNZC3	V97U0406C	ND	F	S	M	C	G4.204	00	ZSU	89979F	
SMNZC4	V97U0407C	G	F	S	M	C	G4.204	00	ZSU	89979F	
TLFMX1	V99U6534C	G	F	S	M	P	G4.204	00	GEC	90724D	
VABIAS	V99U6510C	FT/SEC**2	F	S	M	P	G4.204	00	GEC	90724D	
VCO	V97U0431C	FT/SEC	F	S	D	C	G4.204	00	ZSU	89979F	
V_DEF	V97U0536C	FT/SEC	F	S	M	P	G4.204 G4.9	00	ZSU	89979F	
WEIGHT_RTLS	V97U0443C	SLUGS	F	S	M	C	G4.122 G4.204 G4.234	00	GWT	89979F	
XA(1)	V97U0456C	FT	F	S	M	X	G4.204 G4.220 G4.237 G4.9	00	XS3	DC0599	
XA(2)	V97U0457C	FT	F	S	M	X	G4.204 G4.220 G4.237 G4.9	00	XS3	DC0599	
YERRLM	V97U0464C	DEG	F	S	D	X	G4.204 G4.9	00	ZSU	89979F	
Y_RANGE1	V97U0462C	ND	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	
Y_RANGE2	V97U0463C	FT	F	S	D	P	G4.204 G4.9	00	ZSU	89979F	

TABLE 4.8.3-3. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
ZDT1	V99U5055C	ND	F	S	M	P	G4.204	00	GCA	DC0762C	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.8.3-4. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
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NO REQUIREMENTS

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.8.3-5. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S	C A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DTG TIME STEP BETWEEN TAEM GUIDANCE CALLS	V97U6116C	00	+9.6	E-01 SEC	F		S	C G4.204 G4.9	90374C	

TABLE 4.8.3-5. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S P	A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
HDMAX MAXIMUM SINK RATE DURING ALPHA RECOVERY	V99U7439C	00	+7.2	E+75 FT/SEC	F		S P	G4.204	90374C	

TABLE 4.8.3-5. GLIDE RETURN-TO-LAUNCH SITE TAEM GUIDANCE (G4.204) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
RAD_PER_DEG DEGREE TO RADIAN CONVERSION FACTOR	V97U0383C	00	+1.7453293	E-02	RAD/DEG	F	S	C A6.9 G4.1 G4.126 G4.127 G4.128 G4.144 G4.15 G4.158 G4.175 G4.20 G4.201 G4.204 G4.205 G4.209 G4.210 G4.211 G4.213 G4.220 G4.223 G4.226 G4.227 G4.236 G4.237 G4.3 G4.35 G4.36 G4.7 G4.72 G4.9 G4.97 G5.27	93090E	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

4.9 RETURN-TO-LAUNCH-SITE APPROACH AND LANDING GUIDANCE (G4.234, MAJOR MODE 603)

The RTLS approach and landing guidance/control phase (A/L) begins with completion of the RTLS terminal area energy management (TAEM) guidance/control phase and ends when the vehicle comes to a complete stop on the runway.

4.9.1 Requirements Overview

This phase contains guidance functions necessary to steer the orbiter to the runway for touchdown and roll out. Figure 4.9.1-1 shows the guidance function structure for A/L. The approach and landing guidance module executes the longitudinal guidance and lateral guidance modules.

Since the RTLS A/L guidance requirements are effectively identical to that of A/L guidance (Section 4.7), functional requirements will be referenced to Section 4.7 whenever possible. RTLS A/L unique requirements are described in Section E, Supplemental Information. The function of the longitudinal guidance module (Section 4.7.2.1) is to execute functions which:

1. Compute normal acceleration command as output to flight control subsystem (FC).
2. Compute speed brake command as output to FC and displays.
3. Issue a retract body flap command to FC below a predetermined altitude or at A/L initiation.

Note that RTLS A/L longitudinal guidance does not support commands associated with the Remote Control Orbiter (RCO) landing capability.

The function of the lateral guidance module (Section 4.7.2.2) is to execute functions which:

1. Compute roll attitude command as output to FC and displays.
2. Compute wings-level roll command during flat turn.
3. Compute yaw-rate commands to FC during flat turn, touchdown, and rollout.

Auxiliary functions that have common usage to approach and landing guidance, indicated on Figure 4.9.1-1, are discussed in Section 4.7.2.

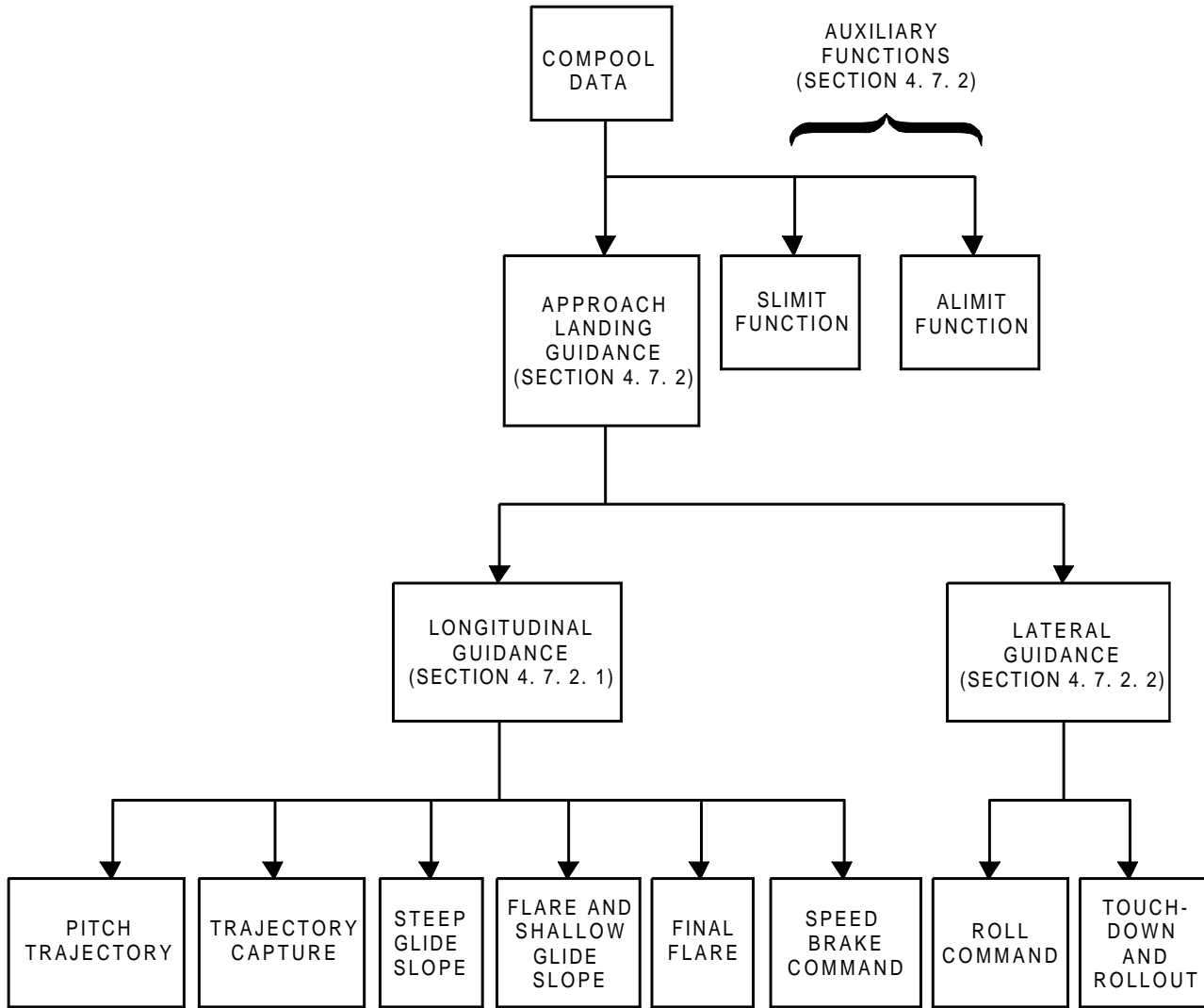


FIGURE 4.9.1-1. Approach and Landing Guidance Function Structure (Section 4.7)

4.9.2 RTLS Approach and Landing Guidance (G4.234)

The RTLS approach and landing phase (A/L) begins with the termination of the RTLS terminal area energy management (TAEM) phase and ends when the vehicle comes to a complete stop on the runway. The A/L guidance automatically acquires and maintains the vehicle on an approach trajectory from TAEM guidance termination to touchdown. Normal acceleration, roll–attitude, and speed brake–position commands are issued for the flight control subsystem to maintain the specified trajectory while the vehicle is airborne. Yaw–rate and wings–level roll–attitude commands are issued during flat turn, touchdown, and roll out to track the runway centerline. During all phases, the orbiter state vector is updated by the navigation subsystem. In the approach phase, the state vector computation may be augmented by additional information from a microwave scanning beam landing system (MSBLS). A/L guidance commands are continued with the flight control subsystem operating in the CSS mode in the pitch and/or roll–yaw axes.

RTLS A/L guidance is partitioned into two functional modes that are operational throughout all subphases: longitudinal guidance and lateral guidance. The input parameters for A/L guidance are derived from the navigation, flight control, and air data subsystems. Output parameters are issued to flight control and displays.

A. Detailed Requirements. A/L guidance is divided into two functions: longitudinal guidance and lateral guidance. The logical process for A/L guidance is as follows:

Process Set 1

- 1.1 Process longitudinal guidance (Section 4.7.2.1).
- 1.2 Process lateral guidance (Section 4.7.2.2).

B. Interface Requirements. The input/output parameters and I–loads/constants for each software function within RTLS A/L guidance are shown in each subsection describing the function. Equivalent internal names for external input parameters are shown in Table 4.9.2–1 in conjunction with subsequent detailed requirements.

C. Processing Requirements. Processing of RTLS A/L guidance must be executed once each guidance cycle throughout the A/L major mode phase. All arithmetic computations are to be done in single precision.

D. Initialization Requirements. At the RTLS TAEM–A/L transition, the RTLS A/L guidance program is executed before the flight control program in the new phase.

E. Supplemental Information. Throughout RTLS A/L phase, functions of Figure 4.7.2–1 are used. These are of three types: (1) trigonometric of high order articulated language (HAL) common usage with single argument, (2) ancillary function blocks with one or more arguments, and (3) Z–transform type requiring storage of previously computed inputs or outputs of a function.

The detailed requirements for RTLS A/L are identical to those for the nominal end-of-mission A/L guidance (Section 4.7.2) except for items which are unique to GRTLS as specified in the following:

1. The vehicle mass parameter (WEIGHT) is not included as a part of the input requirements because it will be satisfied through utilization of the WEIGHT_RTLS I-load (V97U0443C).
2. Due to the use of an I-load in RTLS for vehicle weight, “light” versus “heavy” glide slope reference determination (i.e., IGS = 1 versus IGS = 2) is not a functional requirement for RTLS A/L. Instead, the IGS subscript as used in A/L guidance (Section 4.7) will always maintain a value of one for RTLS, and the appropriate “light” or “heavy” weight-dependent I-loads will be selected before the mission in conjunction with the WEIGHT_RTLS I-loads.
3. RTLS A/L guidance has no requirements for commands associated with the RCO landing capability since the capability will not be attempted during an RTLS.

For a definition of parameters, see Section 5.3.1.

The functional flow for GRTLS A/L Guidance is as provided in section 5.1.3 for A/L Guidance except for items which are unique to GRTLS as specified above. In case of conflict between the flow charts in section 5.1.3 and the requirements in Section 4.9.2, the requirements in Section 4.9.2 shall have precedence.

Table 4.9.2-1. GRTLS A/L Guidance Input/Internal Name Equivalence

MSID	Source Input Name	Guidance Internal Name	Description	Source
V90H1044CE	PHIC_AT	PHIC_AT	Commanded roll angle	GRTLS TAEM GUID
V95L0265CA	H_DOT_ELLIPSOID	H_DOT	Estimated altitude rate	RTLS UPP
V95H0165CA	ALT_WHEELS	H	Alt to rear wheels	RTLS UPP
V95L0178CA	V_GROUNDSPEED	V_G	Groundspeed	RTLS UPP
V95H0220CA	POSITION_WRT_RUNWAY(1)	X	Downrange distance wrt RW	RTLS UPP
V95H0221CA	POSITION_WRT_RUNWAY(2)	Y	Crossrange distance wrt RW	RTLS UPP
V95L0151CA	REL_VEL_MAG	V_I	Ground rel vel magnitude	RTLS UPP
V95H0225CD	COURSE_WRT_RUNWAY	PSI_GND	Course wrt runway center line	RTLS UPP
V95H0261CC	FLT_PATH_ANG	GAMMA	Ground-rel flight path angle	RTLS UPP
V95L0256CC	VELOCITY_WRT_RUNWAY(2)	Y_DOT	Crossrange vel wrt RW	RTLS UPP
V90X1632XB	AUTOP_LAMP	AUTOP_LAMP	Pitch auto flag	GRTLS DAP
V90X1642XB	AUTORY_LAMP	AUTORY_LAMP	Roll/yaw auto flag	GRTLS DAP
V95L3015C	TAS	TAS	GN&C true airspeed	ADTA SOP
V95L3145C	EAS	EAS	GN&C equivalent airspeed	ADTA SOP

Table 4.9.2-1. GRTLS A/L Guidance Input/Internal Name Equivalence				
MSID	Source Input Name	Guidance Internal Name	Description	Source
V96X0050X	WOWLON_IND	WOWLON	Weight on main wheels indicator	LANDING SOP
V96X0051X	FLATTURN_CMD	FLATTURN	Flatturn indicator	LANDING SOP
V93X4476X	(not defined)	GI_CHANGE	Head wind high/low cmd	6.21
V95P3011C	QBAR	QBAR	GN&C dynamic pressure	ADTA SOP
V97U0443C	WEIGHT_RTLS	WEIGHT	Orbiter mass	I-LOAD
V93J0996C	I_SHORT_RW	I_SHORT_RW	Short runway option	6.21

4.9.3 Parameter Tables for GRTLS A/L Guidance (G4.234)

The IDD inputs and outputs are listed in Tables 4.9.3-1 and 4.9.3-2 respectively. Values for the I-loads are contained in the I-load requirements document (JSC-19350); however, I-load definitions applicable to this principal function are listed in Table 4.9.3-3. K-loads are listed in Table 4.9.3-4. Constants are listed in Table 4.9.3-5.

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TABLE 4.9.3-1. INPUT FUNCTIONAL PARAMETERS FOR GRTLS AUTOLAND GUIDANCE (G4.234)

FSSR NAME	M/S ID	NOMENCLATURE	SOURCE	UNITS	DATA TYPE	P R E C	LAST CR	R E V
ALT_WHEELS	V95H0165CA	ALT TO REAR WHEELS/NAV BASE(ENTRY)	RTLS UPP	FT			93017G	*
AUTOP_IND/AUTOP_LAMP	V90X1632XB	PITCH AUTO FLAG	GRTLS DAP				92522D	
AUTORY_IND/AUTORY_LAMP	V90X1642XB	ROLL/YAW AUTO FLAG	GRTLS DAP				92522D	
COURSE_WRT_RW/PSD	V95H0225CD	COURSE WRT RW CENTERLINE	RTLS UPP	DEG			93017G	*
EAS	V95L3145C	GN&C EQUIVALENT AIRSPEED	ADTA SOP	FT/S	SPL		93017G	*
FLATTURN_CMD	V96X0051X	FLATTURN INDICATOR	LANDING SOP					
FLT_PATH_ANG/GAMMA	V95H0261CC	GROUND-REL FLT PATH ANGLE	RTLS UPP	SPECIAL			93017G	*
GI_CHANGE	V93X4476X	HEAD WIND HI/LO CMD	HORIZ SIT DISP		BD		93017G	*
H_DOT_ELLIPSOID/H_DOT	V95L0265CA	EST ALTITUDE RATE	RTLS UPP	FT/S	SPL		93017G	*
I_SHORT_RW	V93J0996C	SHORT RUNWAY OPTION	HORIZ SIT DISP				93017G	*
PHIC_AT	V90H1044CE	COMMANDED ROLL ANGLE	GRTLS TAEM GUID	DEG			93017G	*
POSN_WRT_RW(1)/X	V95H0220CA	DOWNRANGE DISTANCE WRT RW	RTLS UPP	FT			93017G	*
POSN_WRT_RW(2)/Y	V95H0221CA	CROSSRANGE DISTANCE WRT RW	RTLS UPP	FT			93017G	*
QBAR/QBAR_AD	V95P3011C	GN&C DYNAMIC PRESSURE	ADTA SOP	LBF/FT2	SPL		93017G	*
REL_VEL_MAG	V95L0151CA	GND REL VEL MAGNITUDE IN M50 SYS	RTLS UPP	FT/S	SPL		93017G	*
TAS	V95L3015C	GN&C TRUE AIRSPEED	ADTA SOP	FT/S	SPL		93017G	*
VEL_WRT_RW(2)/YDOT	V95L0256CC	CROSSRANGE VEL WRT RW	RTLS UPP	FT/S			89250B	
V_GROUNDSPEED/VH	V95L0178CA	GROUNDSPEED	RTLS UPP	FT/S			92389C	
WOWLON_IND	V96X0050X	WEIGHT ON MAIN WHEELS INDICATOR	LANDING SOP		BD		93017G	*

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.9.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM GRTLS AUTOLAND GUIDANCE (G4.234)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
DELTA_SBE	V90U1036CB	SPBK CMD/ERROR COMPONENT	TLM	DEG				
DELTA_SBI	V90U1037CB	SPBK CMD/INTEGRAL ERROR COMPONENT	TLM	DEG				
DR_TOTAL	V90L1084CB	PROJECTED ENERGY RANGE AT TD	TLM	FT				
DSBC_AL	V90H1011CD	SPEEDBRAKE ANGLE COMMAND-AUTO LAND	DL FMT 21/1 GRTLS DAP SPI PROC VERT SIT DIP	DEG			93017G	*
EAS_FILT	V90L1039CB	FILTERED EQUIVALENT AIRSPEED	TLM	FT/S				
F_MODE	V90X1040XB	FLARE &SHALLOW GLIDESLOPE MODE FLG	TLM					
GAMMA_C3	V90H1068CB	FLIGHT PATH COMMAND-FSGS	TLM	DEG				
GAMMA_C3_DOT	V90R1069CB	FLIGHT PATH COMMAND RATE-FSGS	TLM	DEG/S				
GAMMA_ERROR	V90H1067CB	FLIGHT PATH ERROR	TLM	DEG				
HUD_SB_RETRACT	V72X4044XB	HUD SPEEDBRAKE RETRACT IND	HUDE1 HUDE2					
H_DOT_ERROR	V90R1062CB	ALTITUDE RATE ERROR	TLM	FT/S				
H_ERROR	V90H1061CB	ALTITUDE ERROR	DL FMT 21/A E/L ADI PROC HORIZ SIT SPEC HUD PROC	FT			93017G	*
H_REF	V90H1051CB	REFERENCE ALTITUDE	TLM	FT				
H_REF_DOT	V90H1071CB	ALTITUDE RATE REFERENCE-FF	TLM	FT/S				
H_REF_T	V90H1053CB	ALTITUDE REFERENCE-FSGS	TLM	FT				
H_REF_T_DOT	V90H1057CB	ALTITUDE RATE REFERENCE-FSGS	TLM	FT/S				
IGI	V90J1047CD	GROUND INTERCEPT INDEX	HUD PROC					
LAT_MODE	V90X1085XB	LATERAL MODE INDICATOR	TLM					
NZC	V90A1025CC	NORMAL ACCEL CMD	DL FMT 21/A GRTLS DAP	G			93017G	*
NZ_C	V90A1016CB	UNLIMITED NORMAL ACCEL COMMAND	TLM	G				
NZ_C1	V90A1017CB	NORMAL ACCELERATION COMMAND ONE	TLM	G				
NZ_C1H	V90A1021CB	NORM ACCEL CMD ALT RATE ERROR COMP	TLM	G				
NZ_C1I	V90A1022CB	NORM ACCEL CMD ONE INTEGRAL COMP	TLM	G				
NZ_C2H	V90A1023CB	NORM ACC CMD TWO ALT ERR COMP	TLM	G				
NZ_C2I	V90A1024CB	NORM ACCEL CMD TWO INTEGRAL COMP	TLM	G				
NZ_C3	V90A1019CB	NORMAL ACCELERATION COMMAND THREE	TLM	G				
NZ_C4	V90A1020CB	NORMAL ACCELERATION COMMAND FOUR	TLM	G				
PHIC_AL	V90H1044CD	COMMANDED ROLL ANGLE	DL FMT 21/A E/L ADI PROC GRTLS DAP	DEG			93017G	*
PHIC_UL	V90H1031CE	UNLIMITED ROLL COMMAND	TLM	DEG				
P_MODE	V90Q1100CB	PITCH SUBPHASE MODE INDICATOR	HUD PROC TLM					
RC	V90R1027CB	AUTOLAND YAW RATE CMD	GRTLS DAP TLM	DEG/S				
RETRACT_BF	V90X1030XB	BF RETRACT FLAG	GRTLS DAP					

TABLE 4.9.3-2. OUTPUT FUNCTIONAL PARAMETERS FROM GRTLS AUTOLAND GUIDANCE (G4.234)

FSSR NAME	M/S ID	NOMENCLATURE	DESTINATION	UNITS	DATA TYPE	P R E C	LAST CR	R E V
R_GND_AP	V90H1034CB	RANGE TO RUNWAY TARGET	HORIZ SIT SPEC TLM	FT				
V_ERROR	V90L1064CB	VELOCITY ERROR	VERT SIT DIP TLM	FT/S				
V_T_FILT	V90L1065CB	FILTERED TRUE AIRSPEED	TLM	FT/S				
V_WIND_FILT	V90L1083CB	FILTERED WIND SPEED	TLM	FT/S				
V_WIND_X	V90L1082CB	COMPUTED WIND SPEED	TLM	FT/S				

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

**Rate Codes: (HDR Only) 1 = 1 sample/sec 2 = 5 samples/sec 3 = 12.5 samples/sec 4 = 25 samples/sec 5 = 100 samples/sec
(HDR and LDR) A = 1 sample/sec B = 5 samples/sec C = 12.5 samples/sec D = 25 samples/sec E = 100 samples/sec**

TABLE 4.9.3-3. GRTLS AUTOLAND GUIDANCE (G4.234) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
A_40	V97U0005C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
A_DR_WT(1)	V99U8830C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
A_INT	V97U0000C	DEG*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
A_VWF	V99U8820C	SEC**-1	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
B_DR_WT(1)	V99U8832C	FT/SLUG	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
DSBC_WW	V96U9365C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
DT_LAG_NZ	V96U9364C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
GAMMA_REF_1(1)	V97U0233C	DEG	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
GAMMA_REF_2	V97U0235C	DEG	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
H_CLOOP	V97U0265C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_DECAY	V97U0266C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_ERROR_MAX	V97U0269C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_FF	V97U0270C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_FLARE	V97U0271C	FT	F	S	M	C	G4.10 G4.234	00	GLC	90960E	
H_INTMX	V97U0272C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
H_K(1,1)	V97U0273C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
H_K(1,2)	V97U0274C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
H_MIN	V97U0277C	FT	F	S	D	C	G4.10 G4.234	00	ZFH	92938B	
H_NO_ACC	V97U0278C	FT	F	S	D	C	G4.10 G4.234 G4.252	00	ZFH	92938B	
H_SBR_TABLE(1)	V97U0281C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_SBR_TABLE(2)	V97U0282C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
H_TD1_DOT	V97U0284C	FT/SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	

TABLE 4.9.3-3. GRTL5 AUTOLAND GUIDANCE (G4.234) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
H_TD2_DOT	V97U0285C	FT/SEC	F	S	D	C	G4.10 G4.234 G4.252	00	ZFH	92938B	
H_WL	V97U0286C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
INIT_RET_BF	V97U0492C	ND	BI				G4.10 G4.234	01 03	ZFH	DC2711	
K_DH	V99U8822C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_DR_DH	V99U8823C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_DR_SRW(1)	V97U1293C	FT	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
K_DR_SRW(2)	V97U1294C	FT	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
K_FLR	V97U0299C	G*SEC**2/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_FF	V97U0303C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_FSGS	V97U0304C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_SGS	V97U0305C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HDOT_TC	V97U0306C	G*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_HINT1	V97U0307C	G/FT*SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_FSGS	V97U0300C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_SGS	V97U0301C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_H_TC	V97U0302C	G/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_IFLR	V97U0308C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_INT_FSGS	V97U0309C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(1,1)	V96U9356C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(1,2)	V96U9357C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(2,1)	V96U9358C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(2,2)	V96U9359C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(3,1)	V96U9360C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	

TABLE 4.9.3-3. GRTL5 AUTOLAND GUIDANCE (G4.234) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
K_R_TAB(3,2)	V96U9361C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(4,1)	V96U9362C	SEC**-1	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_R_TAB(4,2)	V96U9363C	LBS/FT**2	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SB	V97U0312C	DEG*SEC/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SBI	V97U0313C	DEG/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_SB_DR	V99U8828C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
K_Y1	V97U0315C	DEG/FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
K_YDOT	V97U0314C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
NZC_LIM	V97U0323C	G	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
N_FADER	V97U0320C	ND	I	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M1	V97U0339C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M2	V97U0340C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
PHI_M3	V97U0341C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
R(1,1)	V97U0379C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
R(1,2)	V97U0380C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
SB_MAX_RET	V97U1295C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
SB_MAX_TD(1)	V97U1296C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
SB_MAX_TD(2)	V97U1297C	DEG	F	S	M	P	G4.10 G4.234	00	GLC	92551B	
SB_REF	V97U0397C	DEG	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
SIGMA(1)	V97U0402C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
S_DH	V99U8824C	FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_DR_DH	V99U8829C	FT/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_DR_VEL	V99U8825C	FT*SEC/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	

TABLE 4.9.3-3. GRTL5 AUTOLAND GUIDANCE (G4.234) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
S_DR_WIND	V99U8826C	FT*SEC/FT	F	S	M	P	G4.10 G4.234	00	GLC	DC2287	
S_SB_DR(1)	V99U8834C	DEG/FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
TAU_GAMMA	V97U0410C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
TAU_TD	V97U0411C	SEC	F	S	D	C	G4.10 G4.234	00	ZFH	92938B	
TAU_TD1	V97U0412C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
TAU_TD2	V97U0413C	SEC	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
V_REF(1)	V97U0418C	FT/SEC	F	S	M	C	G4.10 G4.234	01 03	GL1 GL3	92938B	
WEIGHT_RTLS	V97U0443C	SLUGS	F	S	M	C	G4.122 G4.204 G4.234	00	GWT	89979F	
X_AIM_PT	V97U0445C	FT	F	S	M	C	G4.10 G4.154 G4.220 G4.234 G4.237 G4.252 G5.27 G5.7	01 03	GL1 GL3	93090E	
X_EXP(1,1)	V97U0446C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
X_EXP(1,2)	V97U0447C	FT	F	S	M	C	G4.10 G4.234 G4.252	01 03	GL1 GL3	92938B	
X_K(1,1)	V97U0450C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
X_K(1,2)	V97U0451C	FT	F	S	M	P	G4.10 G4.234	01 03	GL1 GL3	DC2356	
X_ZERO(1)	V97U0454C	FT	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
X_ZERO(2)	V97U0455C	FT	F	S	M	C	G4.10 G4.234 G4.252	00	GLC	92938B	
Y_INLIM	V97U0460C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	
Y_LIMIT	V97U0461C	FT	F	S	D	P	G4.10 G4.234	00	ZFH	DC2711	

TABLE 4.9.3-3. GRTLS AUTOLAND GUIDANCE (G4.234) I-LOADS

FSSR NAME	MSID	ENG UNITS	DT	PR	D	S	PR FCTN	MC	CAT	LAST CR	R E V
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NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.9.3-4. GRTLS AUTOLAND GUIDANCE (G4.234) K-LOADS

FSSR NAME DESCRIPTION	MSID	MC	KLOAD VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
A_13	V97U0002C	00	+1.0	E+00	SEC**-1	F	S	P G4.10 G4.234	29579B	
A_14	V97U0003C	00	+1.0	E+00	SEC**-1	F	S	P G4.10 G4.234	29579B	
A_3	V97U0004C	00	+1.0	E+01	SEC**-1	F	S	P G4.10 G4.234	29579B	
GAMMA_CAPTURE	V97U0229C	00	+2.0000000	E+00	DEG	F	S	P G4.10 G4.234	29579B	
H_ERROR_CAPTURE	V97U0268C	00	+5.00	E+01	FT	F	S	P G4.10 G4.234	29579B	
PSI_CAP	V97U0350C	00	+2.0	E+00	DEG	F	S	P G4.10 G4.234	29579B	
P_MODE_INITIAL	V97U0326C	00	+1		ND	I	S	P G4.10 G4.234	29579B	
SB_MAX	V97U4145C	00	+9.86	E+01	DEG	F	S	A G4.10 G4.234 G4.48	93015C	
TQ_LAT	V97U0416C	00	+4.0	E+00	SEC	F	S	P G4.10 G4.234	29579B	
T_Q	V97U0409C	00	+4.0	E+00	SEC	F	S	P G4.10 G4.234	29579B	
V_LIMIT	V97U0417C	00	+1.00	E+01	FT/SEC	F	S	P G4.10 G4.234	29579B	
Y_CAP	V97U0458C	00	+5.00	E+01	FT	F	S	P G4.10 G4.234	29579B	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

TABLE 4.9.3-5. GRTLS AUTOLAND GUIDANCE (G4.234) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
DEG_PER_RAD RADIAN TO DEGREE CONVERSION FACTOR	V97U0112C	00	+5.72957795131E+01	DEG/RAD	F		S C	A6.9 G4.10 G4.126 G4.127 G4.128 G4.175 G4.20 G4.201 G4.204 G4.208 G4.21 G4.213 G4.220 G4.226 G4.227 G4.23 G4.234 G4.237 G4.24 G4.25 G4.35 G4.36 G4.5 G4.6 G4.66 G4.8 G4.9 G4.97 G5.26 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	
DT A/L GUIDANCE SAMPLE TIME INTERVAL	V97U6115C	00	+1.6	E-01 SEC	F		S C	G4.10 G4.234	90374C	

TABLE 4.9.3-5. GRTLS AUTOLAND GUIDANCE (G4.234) CONSTANTS

FSSR NAME DESCRIPTION	MSID	MC	CONSTANT VALUE	ENG UNITS	DT	P R	S	PR FCTN	LAST CR	R E V
GO EARTH GRAV ACCEL CONSTANT	V90A7622C	00	+3.2174049	E+01 FT/SEC**2	F		S P	A6.9 G4.10 G4.105 G4.126 G4.204 G4.208 G4.22 G4.220 G4.227 G4.234 G4.237 G4.36 G4.8 G4.9 G5.27 V4.10 V4.11 V4.11B V4.11C V4.9A	93090E	

NOTE: REFERENCE TABLE 1.3-1 FOR EXPLANATION OF DATA ELEMENTS.

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5.0 SUPPLEMENTARY MATERIAL

5.1 PARAMETERS/FLOW CHARTS

Detailed guidance requirements for the entry, TAEM, approach/landing, GRTLS TAEM, and GRTLS approach/landing phases (Major Modes 304, 305, 602, and 603) are presented in Sections 4.5, 4.6, 4.7, 4.8, and 4.9.

The supplementary section contains tables of non-I-load parameters, including definitions, used in the descent guidance programs and function flow charts.

5.1.1 Entry Guidance

The entry guidance parameters are shown in Table 5.1.1-1.

Table 5.1.1-1. Initial Definition of Entry Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
A(1,2)	Parameter for D–V quadratic	EGINIT, EGRP	0	F
ALDCO	Temporary variable in Phase 3 reference parameters	EGREF	0	F
ALDREF	Vertical L/D reference	EGLDVCMD	0	F
ALPCMD	Angle–of–attack command	EGALPCMD, EGROLCMD, EGLDVCMD	0	F
ALPDOT	Rate of change of ALPCMD	EGALPCMD, EGLDVCMD	0	F
ALPO	Past value of ALPCMD	EGALPCMD	0	F
ARG(1)	Cosine of commanded roll angle	EGROLCMD	1	F
ARG(2)	Cosine of unlimited roll command	EGROLCMD	1	F
ARG(3)	Cosine of roll reference angle	EGROLCMD	1	F
A2	Temporary variable used in computing range and updating D23	EGRP	0	F
A44	Exponential term in \dot{C}_D correction term	EGLDVCMD	0	F
CAG	Pseudo energy/mass used in transition (L/D) reference	EGCOMN, EGTRAN	0	F
CDCAL	Calculated drag coefficient	EGLDVCMD	0	F
CDDOTC	Calculated \dot{C}_D	EGLDVCMD	0	F
CQ1(1,2)	Constants in Ith temperature control D–V quadratic	EGRP, EGREF	0	F
CQ2(1,2)	VE coefficients in Ith temperature control D–V quadratic	EGRP, EGREF	0	F
CQ3(1,2)	VE ² coefficients in Ith temperature control D–V quadratic	EGRP, EGREF	0	F
C1	dD/dE in transition	EGTRAN, EGEXEC	0	F
C16	d(L/D)/dD	EGGNSLCT, EGLDVCMD	0	F
C17	d(L/D)/d \dot{h}	EGGNSLCT, EGLDVCMD	0	F
C2	Component of L/D reference	EGREF, EGLDVCMD	0	F
C4	\dot{C}_D correction term	EGLDVCMD	0	F
DD	Drag minus drag reference	EGGNSLCT, EGLDVCMD	0	F
DDS	Limited value of DD	EGLDVCMD	0	F
DDP	Previous value of DD	EGLDVCMD	0	F
DLIM	Maximum value of DREFP in transition	EGTRAN	0	F
DLRDOT	\dot{h} feedback correction term	EGLDVCMD	0	F
DLZRL	Test variable in roll angle computation	EGLDVCMD	0	F
DRDD	Derivative of range wrt drag	EGRP, EGREF4, EGTRAN	0	F

Table 5.1.1-1. Initial Definition of Entry Guidance Parameters

Name	Description	Internal Use	Initial Value	Type
DREF(1,2)	DREFP for Ith temperature control D-V quadratic	EGREF	0	F
DREFP	Drag reference used in controller	EGREF, EGREF4, EGGNSLCT, EGTRAN	0	F
DREFPT	DREFP-DF in transition phase	EGTRAN	0	F
DREFP1	DREFP in equilibrium glide	EGREF	0	F
DREFP3	DREFP test value for transition to Phase 3	EGREF, EGEXEC	0	F
DREFP4	DREFP test value for transition to Phase 4	EGREF, EGEXEC	0	F
DREFP5	DREFP test value for transition to Phase 5	EGEXEC, EGCOMN	0	F
DRF	Test value for transition to D23-VB1 quadratic reference parameters	EGREF	0	F
DX(1,2)	Normalized values of DREFP	EGRP, EGINIT	0	F
DZOLD	Previous value of DELAZ	EGINIT, EGLODVCMD	0	F
DZSGN	Change in DELAZ	EGLODVCMD	0	F
D23L	Lower limit on D23	EGRP	0	F
D231	First updated value of D23	EGRP	0	F
EEF	Energy/mass	EGTRAN, EGCOMN	0	F
EG_END	Entry guidance termination flag	EGEXEC, EGINIT	OFF	D
HDTRF (1,2)	Altitude rate reference during temperature control phase	EGREF	0	F
HS	Altitude scale height	EGSCALEHT, EGCOMN, EGREF, EGREF4, EGTRAN, EGLODVCMD	0	F
IALP	ALPCMD segment counter	EGINIT, EGALPCMD	6	I
ISLECT	Entry guidance subphase counter	EGINIT, EGLODVCMD, EGEXEC, EGCOMN	1	I
DYL	Auto PTI DELAZ deadband	EGINIT	0	F
DYLN	Auto PTI DELAZ deadband counter	EGINIT	0	I
ITRAN	Transition initialization flag	EGINIT, EGRP, EGTRAN, EGREF4	OFF	D
LMFLG	Saturated roll command flag	EGINIT, EGLODVCMD	0	I
LMN	Maximum value of LODV	EGLODVCMD, EGROLCMD	0	F
LODV	Vertical L/D command	EGROLCMD, EGLODVCMD, EGPEP	0	F
LODX	Unlimited vertical L/D command	EGPEP, EGROLCMD, EGLODVCMD	0	F
Q(1,2,3)	DREFP/VE in temp control phase	EGRP	0	F
RCG	Constant drag phase range	EGRP	0	F

Table 5.1.1-1. Initial Definition of Entry Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
RCG1	Constant component of RCG	EGRP, EGINIT	0	F
RDTRF	Altitude rate reference	EGCOMN, EGREF4, EGLODVCMD, EGTRAN, EGREF	0	F
RDTRF	Nominal value for altitude rate reference	EGLODVCMD	0	F
RDTRF1	RDTRF in Phase 3	EGREF	0	F
RDTRFT	RDTRF in transition phase	EGCOMN	0	F
REQ1	Equilibrium glide range x D23	EGRP	0	F
RER1	Transition phase range	EGTRAN	0	F
RF(1,2)	Ith range segment in temp control Phase x D23	EGRP	0	F
RFF1	Temperature control range x D23	EGRP	0	F
RK2RLP	Past value of RK2ROL	EGINIT, EGLODVCMD	0	F
RK2ROL	Sign of roll command	EGINIT, EGLODVCMD, EGROLCMD	0	F
ROLLC(1)	Roll angle command about body axis	EGROLCMD	0	F
ROLLC(2)	Unlimited roll command	EGROLCMD	0	F
ROLLC(3)	Roll reference angle	EGROLCMD	0	F
RPT	Desired range at VQ	EGINIT, EGRP, EGREF4, EGCOMN	0	F
R23	Range during Phases 2 and 3	EGRP	0	F
R231	Phase 2 and 3 range x D23	EGRP	0	F
START	Entry guidance first pass flag	EGEXEC, EGINIT, EGRP	0	I
T1	Equilibrium glide vertical lift acceleration	EGCOMN, EGLODVCMD	0	F
T2	Constant drag level to reach target	EGEXEC, EGINIT, EGREF, EGCOMN, EGREF4	0	F
T2DOT	Rate of change of T2	EGRP, EGCOMN	0	F
T2OLD	Old T2 value	EGCOMN	0	F
V(1,2,3)	Velocity sampling points for temp control numerical range prediction	EGRP	0	F
VB2	VB^2	EGINIT, EGRP, EGREF	0	F
VCG	Phase 3–4 boundary velocity	EGRP, EGINIT, EGEXEC	0	F
VE2	VE^2	EGCOMN, EGRP, EGTRAN, EGREF, EGLODVCMD	0	F
VF(1,2)	Upper velocity bounds for Ith temperature control range segment	EGRP, EGINIT	0	F
VO(1,2)	Initial velocities for D–V quadratics	EGINIT, EGRP	0	F

Table 5.1.1-1. Initial Definition of Entry Guidance Parameters

Name	Description	Internal Use	Initial Value	Type
VQ2	VQ^2	EGINIT, EGCOMN, EGRP	0	F
VSAT2	$VSAT^2$	EGCOMN, EGINIT, EGLODVCMD	0	F
VSIT2	$VS1^2$	EGINIT, EGRP, EGREF	0	F
VTRB	Velocity to lockout \dot{h} correction	EGPEP, EGLODVCMD	0	F
VX(1,2)	Velocities where $dD/dV = 0$ in Ith temp control D-V quadratic	EGRP	0	F
VTRB1	Velocity to lockout auto PTI's	EGLOVCMD	0	F
XLOD	Limited lift/drag ratio	EGCOMN, EGPEP, EGTRAN, EGLODVCMD, EGROLCMD	0	F
YL	Maximum heading error absolute value	EGLODVCMD	0	F
ZK	Gain on \dot{h} feedback	EGLODVCMD	0	F
ACLAM	Upper limit for angle-of-attack command	EGROLCMD	0	F
ACLIM	Lower limit for angle-of-attack command	EGROLCMD	0	F
ACMD1	Scheduled angle-of-attack command	EGALPCMD, EGROLCMD	0	F
ALMNXD	Roll command limit when ICT = 1	EGROLCMD	0	F
C20	$d(\alpha)/d(C_D)$ gain	EGLEOVCM	0	F
DELALF	Delta α from schedule	EGROLCMD	0	F
DELALP	Commanded α increment	EGLODVCMD, EGROLCMD	0	F
DLRDTZ	Zero \dot{h} bias command	EGINIT, EGLODVCMD	OFF	D
D23	Reference drag level of equilibrium glide and anchor drag level of temperature control phase	EGINIT, EGRP, EGREF	0	F
ICT	Alpha modulation flag	EGINIT, EGGNSLCT, EGLODVCMD, EGROLCMD	0	I
IDBCHG	Lateral deadband flag	EGINIT, EGLODVCMD	0	I
RDEALF	Roll bias for α modulation	EGROLCMD	0	F
RLM	Roll command limit	EGROLCMD	0	F
YL1	DELAZ deadband to lockout auto PTI's	EGLODVCMD	0	F
ALP_VT_DRG	Low-energy logic: angle-of-attack command limit to protect vertical tail thermal	EGROLCMD	0	F
ALP_VT_LM	Low-energy logic: angle-of-attack command limit to protect vertical tail thermal	EGROLCMD	0	F
ALP_WLE	Low-energy logic: angle-of-attack command limit to protect wing leading edge thermal	EGROLCMD	0	F
ALPCA1	Low-energy logic: filtered angle-of-attack command limit to protect thermal	EGROLCMD	0	F

Table 5.1.1-1. Initial Definition of Entry Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
ALPCA2	Low-energy logic: unfiltered angle-of-attack command limit to protect thermal	EGROLCMD	0	F
ALPHPO_HI	Low-energy logic: maximum initial pullout alpha command limit	EGINIT, EGROLCMD	0	F
VI_INIT	Low-energy logic: initial value of inertial velocity	EGINIT, EGROLCMD	0	F

5.1.2 TAEM Guidance

The TAEM guidance parameters are shown in Table 5.1.2-1.

Table 5.1.2-1. Initial Definition of TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
A	Temporary variable in ground track computation	GTP	0	F
ALPH	Temporary variable in NZC computation	TGNZC	0	F
ALPNZUL	DNZCF upper limit based on ALPUL	TGNZC	0	F
ARCAC	Acquisition turn arc length	GTP	0	F
ARCHA	Heading alignment turn arc length	GTP	0	F
AUTOP_LAMP_PAST	Past pitch axis auto mode indicator	TGTRAN	OFF	D
AUTORY_LAMP_PAST	Past roll/yaw axis auto mode indicator	TGTRAN	OFF	D
B	Temporary variable in ground track computation	GTP	0	F
BAILOUT_ARM	Bailout arm flag	TGSBC, TGPHIC	OFF	D
BAILOUT_BANK	Bailout roll control engaged flag	TGTRAN, TGPHIC	OFF	D
BAILOUT_PITCH	Bailout pitch control engaged flag	TGTRAN, TGNZC	OFF	D
DEF_ADO	Past value of DEF_AD	TGINIT, TGCOMP	OFF	D
DHDRRF	Tangent of reference flight path angle	TGCOMP, TGNZC	0	F
DNZC	Unlimited N_z command	TGNZC	0	F
DNZCD	Rate of change of DNZC	TGNZC	0	F
DNZCF	Filtered DNZC	TGNZC	0	F
DNZCL	Temporary variable in NZC computation	TGNZC	0	F
DNZLL	Minimum value of NZC	TGINIT, TGTRAN, TGNZC	0	F
DNZUL	Maximum value of NZC	TGINIT, TGTRAN, TGNZC	0	F
DPHI	Variable in roll command fader	TGPHIC	0	F
DPSAC	Heading error from tangency with HAC in ACQ phase	GTP, TGPHIC	0	F
DRPRED	RPRED + XALI	TGCOMP	0	F
DSBC	Unlimited speed brake command	TGSBC	0	F
DSBC_AT	Speed brake command	TGSBC	0	F
DSBE	Component of DSBC due to QBERR	TGSBC	0	F
DSBI	QBERR integral term of DSBC	TGINIT, TGSBC	0	F

Table 5.1.2-1. Initial Definition of TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
EAS_CMD	Equivalent airspeed command	TGCOMP	0	F
EMAX	Energy over weight used to calculate EOWNZUL	TGNZC, TGCOMP	0	F
EMEP	Energy over weight used for MEP determination	TGTRAN, TGCOMP	0	F
EMIN	Energy over weight used to calculate EOWNZLL	TGNZC, TGCOMP	0	F
EN	Energy over weight reference	TGCOMP, TGTRAN, TGNZC	0	F
EOW	Energy over weight	TGCOMP, TGTRAN, TGNZC	0	F
EOWNZUL	DNZC upper limit based on EMAX	TGNZC	0	F
EOWNZLL	DNZC lower limit based on EMIN	TGNZC	0	F
ES	Energy over weight used for S–turn determination	TGTRAN, TGCOMP	0	F
GCONT	Correction to FC turn coordination term for S–turns	TGNZC	0	F
GDH	Gain on HDERR and HERROR in computing DNZC	TGNZC	0	F
HDERR	Altitude rate error in computing DNZC	TGNZC	0	F
HDREF	Reference altitude rate	TGNZC	0	F
HERROR	Altitude error from reference altitude	TGCOMP, TGNZC	0	F
HREF	Reference altitude	TGCOMP	0	F
ICGUID	Bailout pitch axis initialization flag	TGNZC	OFF	D
IEL	Index for EN and EMEP	TGCOMP, TGTRAN	0	I
IGI	Ground intercept index	TGXHAC	0	I
IGS	Steep glide slope index	TGXHAC, TGCOMP, TGTRAN, TGNZC	0	I
IPHASE	TAEM guidance phase indicator	TGEXEC, TGTRAN, TGNZC, TGSBC, TGPHIC, GTP	1	I
INIT_PASS	TAEM guidance first–pass flag	TGEXEC, TGINIT	ON	D

Table 5.1.2-1. Initial Definition of TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
ISNAPB	Flag to indicate if roll angle has been “snapped” for bailout	TGPHIC	OFF	D
ISNAPP	Flag to indicate if QBAR has been “snapped” for bailout	TGNZC	OFF	D
ISR	PFL roll command fader counter	TGINIT, TGPHIC	1	I
MEDS_DPSAC	MEDS Display heading error	GTP	0	F
MEPALERT	Energy deficiency flag	TGINIT, TGTRAN	FALSE	D
NEP_FB	NEP/MEG flag	TGXHAC, TGTRAN	ON	D
NZC	Normal acceleration command	TGNZC	0	F
PHAVG	Average roll angle during acquisition turn	GTP	0	F
PHIC	Unlimited roll angle command	TGTRAN, TGPHIC	0	F
PHIC_AT	TAEM roll angle command	TGPHIC	0	F
PHIC_ATS	“Snapped” roll angle for bailout	TGPHIC	0	F
PHILIM	Subsonic roll command limit	TGINIT, TGTRAN, TGPHIC	0	F
PHILIMIT	Roll command limit	TGPHIC	0	F
PHIO	Previous value of PHIC during PFL	TGTRAN, TGPHIC	0	F
PSC	Vehicle position angle wrt HAC center	GTP	0	F
PSHA	Heading alignment turn angle	GTP	0	F
PST	Heading to HAC tangency point	GTP	0	F
QBAR	Selected input dynamic pressure	TGINIT, TGCOMP	0	F
QBAR_D	Limited rate of change of QBAR	TGCOMP	0	F
QBARF	Filtered QBAR	TGINIT, TGCOMP, TGNZC	0	F
QBAR_S	“Snapped” QBAR for bailout	TGNZC	0	F
QBD	Filtered dynamic pressure rate	TGINIT, TGCOMP, TGNZC	0	F
QBERR	QBAR error	TGTRAN, TGSBC	0	F
QBLL	Reference dynamic pressure lower limit	TGCOMP	0	F
QBMNNZ	Lower limit on QBAR	TGNZC	0	F
QBMXNZ	Upper limit on QBAR	TGNZC	0	F
QBNZLL	Lower limit on NZC	TGNZC	0	F

Table 5.1.2-1. Initial Definition of TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
QBNZUL	Upper limit on NZC	TGNZC	0	F
QBREF	Dynamic pressure reference	TGCOMP	0	F
RC	Range to HAC tangency point	GTP	0	F
RCIR	Orbiter's radial distance from HAC center	GTP, TGTRAN, TGPHIC	0	F
RDOT	Radial rate deviation from HAC	TGPHIC	0	F
RERRC	HA phase PHIC component due to radial error from HAC	TGPHIC	0	F
RPRED	Predicted ground track range to the runway threshold	GTP, TGCOMP, TGTRAN	0	F
RPRED3	Prefinal initiation range	TGXHAC, TGTRAN	0	F
RT	Range to go where RDOT goes to zero	TGTRAN	0	F
RTAC	Radius of acquisition turn	GTP	0	F
RTAN	Straight line distance to HAC tangency	GTP	0	F
RW_IDO	Past value of runway index	TGEXEC, TGINIT	0	I
S	Sign of roll command for S-turn	TGTRAN, TGPHIC	0	F
SPSI	Temporary variable for determining sign of S-turn roll command	TGTRAN	0	F
TG_END	TAEM guidance termination flag	TGTRAN	FALSE	D
V_PAST	Past value for V	TGINIT, TGCOMP	0	F
XALI	MEP X coordinate of HAC center	TGINIT, TGXHAC, TGCOMP	0	F
XCIR	X distance from nearest HAC center	GTP, TGTRAN, TGPHIC	0	F
XFTC	Nominal X coordinate of HAC center	TGINIT, TGXHAC	0	F
XHAC	X coordinate of HAC center	TGXHAC, GTP	0	F
YCIR	Y distance from nearest HAC center	GTP, TGTRAN, TGPHIC	0	F
YERRC	Prefinal PHIC component due to lateral error	TGPHIC	0	F
YSGN	Sign of Y	GTP, TGTRAN, TGPHIC	0	F

5.1.3 Approach and Landing Guidance

The approach and landing guidance parameters are shown in Table 5.1.3-1.

The flow charts for the Approach/Landing Guidance function are shown in Figures 5.1.3-1 through 5.1.3-8.

Table 5.1.3-1. Initial Definition of A/L Guidance Parameters			
Name	Description	Initial Value	Type
BIAS	Roll command fader term	0	F
DEL_INT	Integral change (SC)	0	F
DELTA	Speed brake error	0	F
DELTA_SBE	Speed brake command, error component	0	F
DELTA_SBI	Speed brake command, integral error component	0	F
DSBS_AL	Speed brake command	0	F
EAS_FILT	Filtered equivalent airspeed	0	F
F_MODE	Flare and shallow glide slope mode flag	0	I
GAMMA_AIR_SYNC	Flight path angle WRT air mass sync	0	F
GAMMA_DOT_MAX	Maximum flight path angle rate	0	F
GAMMA_ERROR	Flight path error	0	F
GAMMA_REF	Flight path angle reference	0	F
GAMMA_REF_T	Flight path angle reference (FSGS)	0	F
GAMMA_C3	Flight path command (FSGS)	0	F
GAMMA_C3_DOT	Flight path command rate (FSGS)	0	F
H_D	Altitude difference (FF)	0	F
H_DDOT_C3	Feed-forward vertical acceleration (FF)	0	F
H_DOT_C3	Feed-forward vertical velocity (FF)	0	F
H_DOT_ERROR	Altitude rate error (PT)	0	F
H_ERROR	Altitude error	0	F
H_ERRORX	Altitude error (FSGS)	0	F
H_FINAL_FLARE	Altitude for final flare	0	F
H_REF	Reference altitude	0	F
H_REF_DOT	Altitude rate reference (FF)	0	F
H_REF_T	Altitude reference (FSGS)	0	F
H_REF_T_DOT	Altitude rate reference (FSGS)	0	F
H_REF_UF_DOT	Altitude rate reference (FF)	0	F
H_SBR	Speed brake retraction altitude	0	F
IGI	Glide slope ground intercept index	0	I
IGS	Steep glide slope index	1	I
ISB	Speed brake retract index	1	I
K_C1G	Flight path error gain (SGS)	0	F

Table 5.1.3-1. Initial Definition of A/L Guidance Parameters			
Name	Description	Initial Value	Type
K_C2H	Altitude error gain (SGS)	0	F
K_HINT	Altitude error integral gain (SGS)	0	F
K_PRED	FSGS open loop command multiplier	0	F
LAT_MODE	Lateral mode indicator	1	I
N	Fader counter (RC)	1	I
NZ_C	Unlimited normal acceleration command	0	F
NZC_MAX	Maximum normal acceleration command (FSGS)	0	F
NZ_C1	Normal acceleration command one (SGS, FSGS, FF)	0	F
NZ_C2	Normal acceleration command two (SGS)	0	F
NZ_C1H	Normal acceleration command one, altitude rate error component	0	F
NZ_C1I	Normal acceleration command one, integral component (FF)	0	F
NZ_C2H	Normal acceleration command two, integral component (SGS, FSGS)	0	F
NZ_C2I	Normal acceleration command two, integral component (SGS, FSGS)	0	F
NZ_C2I_DOT	Derivative of NZ_C2I	0	F
NZ_C3	Normal acceleration command three (SGS, FSGS, FF)	0	F
NZ_C4	Normal acceleration command four (FSGS)	0	F
NZC	Normal acceleration command	0	F
P_MODE	Pitch subphase mode indicator	1	I
PHI_CMD	Lateral command	0	F
PHI_FI	Roll command fader input	0	F
PHIC_UL	Unlimited roll command	0	F
PHI_MAX	Roll command maximum	0	F
PHIC_AL	Roll command	0	F
PSI_COR	Lateral angle (PT)	0	F
RC	Yaw rate command	0	F
RCO_DC_ARM	RCO drag chute arm command	False	D
RCO_DC_DEPLOY	RCO drag chute deploy command	False	D
RCO_LG_ARM	RCO landing gear arm command	False	D
RCO_LG_DEPLOY	RCO landing gear deploy command	False	D
RETRACT_BF	Retract body flap flag	False	D
R_GND_AP	Ground range from aim point	0	F
SBF	Filtered speed brake command	0	F
V_ERROR	Velocity error (SC)	0	F
V_T_FILT	Filtered true airspeed	0	F
X_ZERO	X-intercept of steep glideslope	0	F

Table 5.1.3-1. Initial Definition of A/L Guidance Parameters			
Name	Description	Initial Value	Type
X_ZERO_COR	Corrected X-intercept of steep glide slope	0	F
Y_ERROR	Cross range error	0	F
Y_INT	Cross range error integral	0	F
Y_INT_DOT	Cross range error integrator	0	F

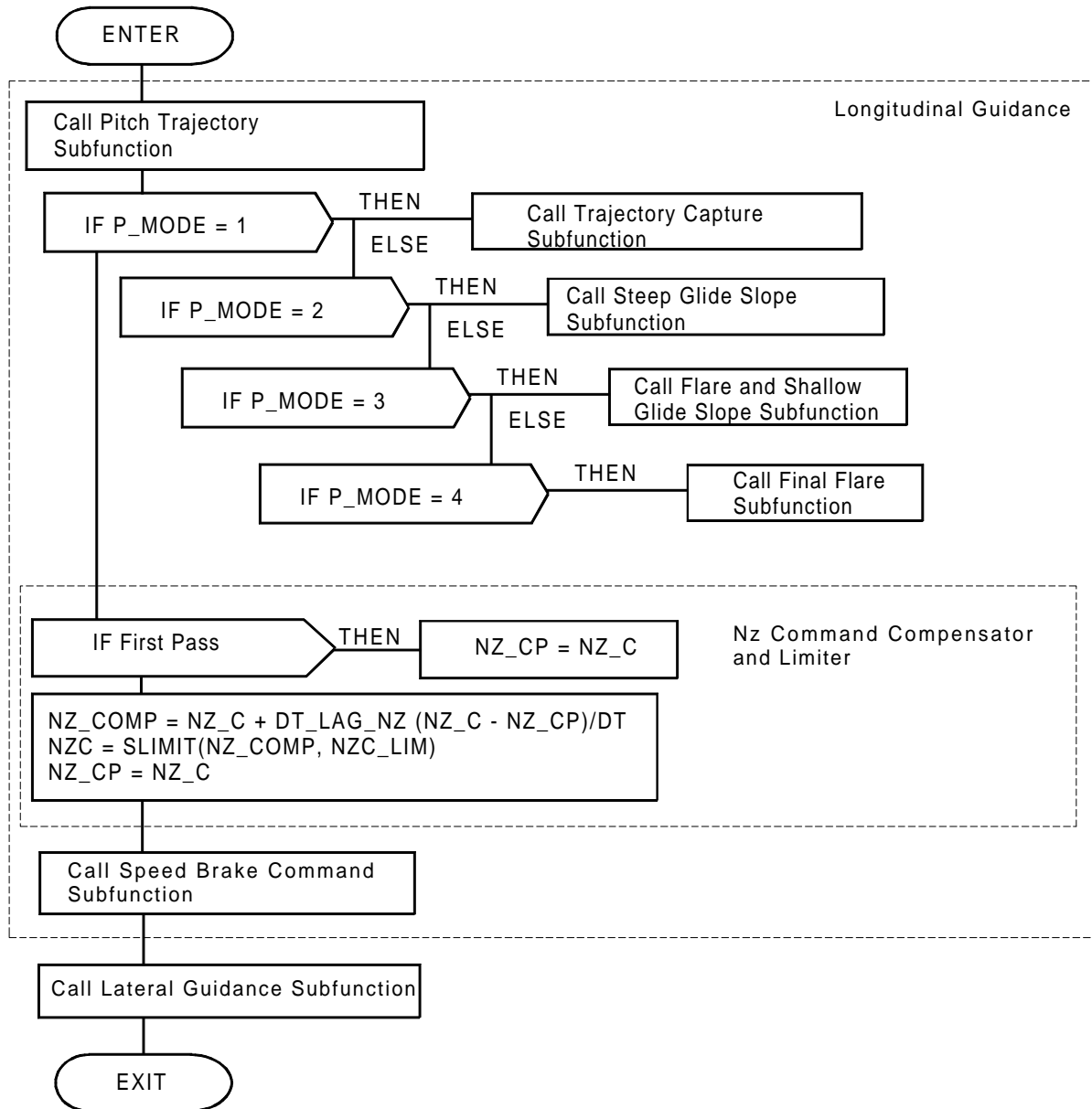


FIGURE 5.1.3-1. Approach/Landing Guidance Functional Flow

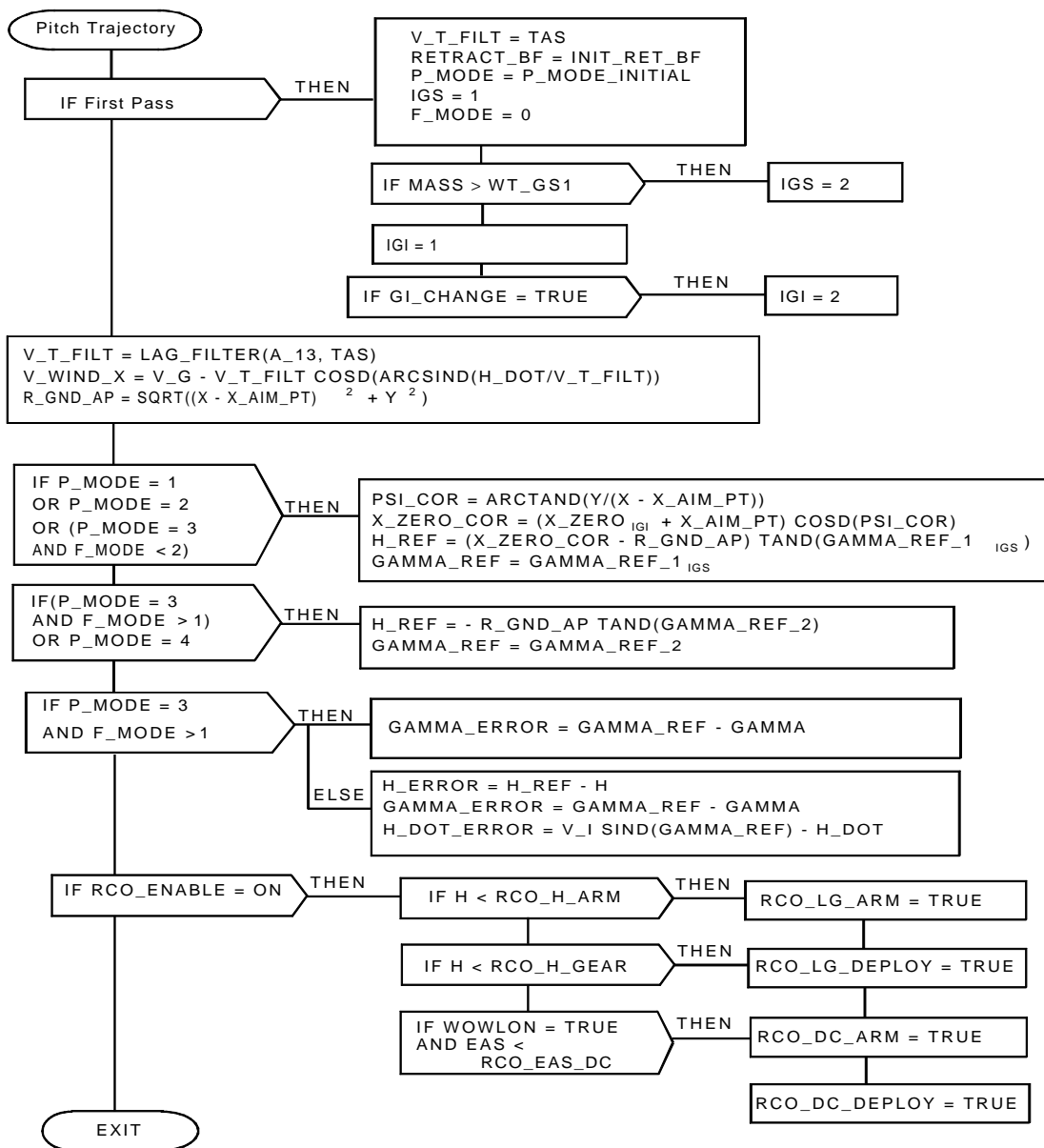


FIGURE 5.1.3-2. Approach/Landing Pitch Trajectory Functional Flow

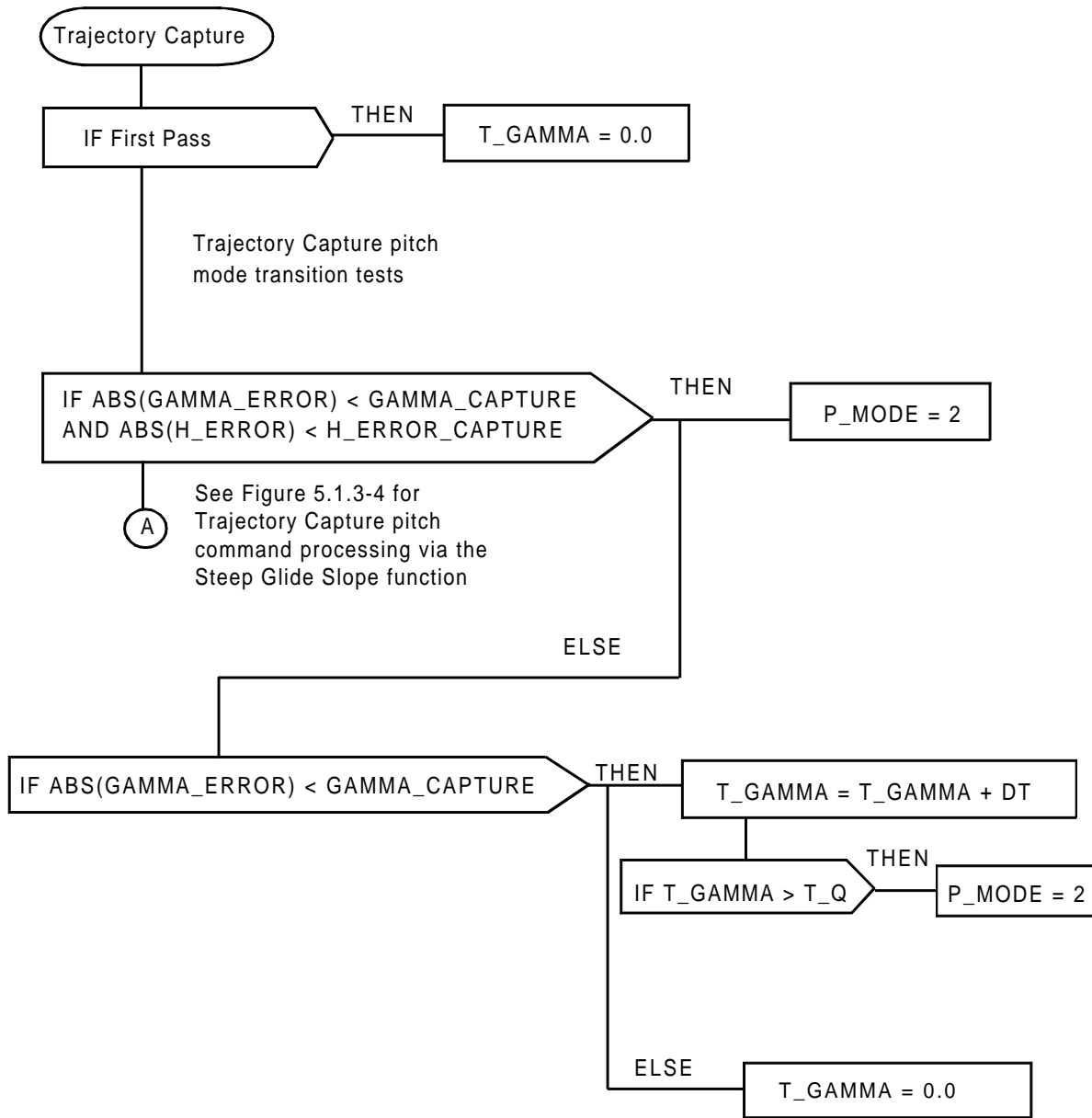


FIGURE 5.1.3-3. Approach/Landing Trajectory Capture Functional Flow

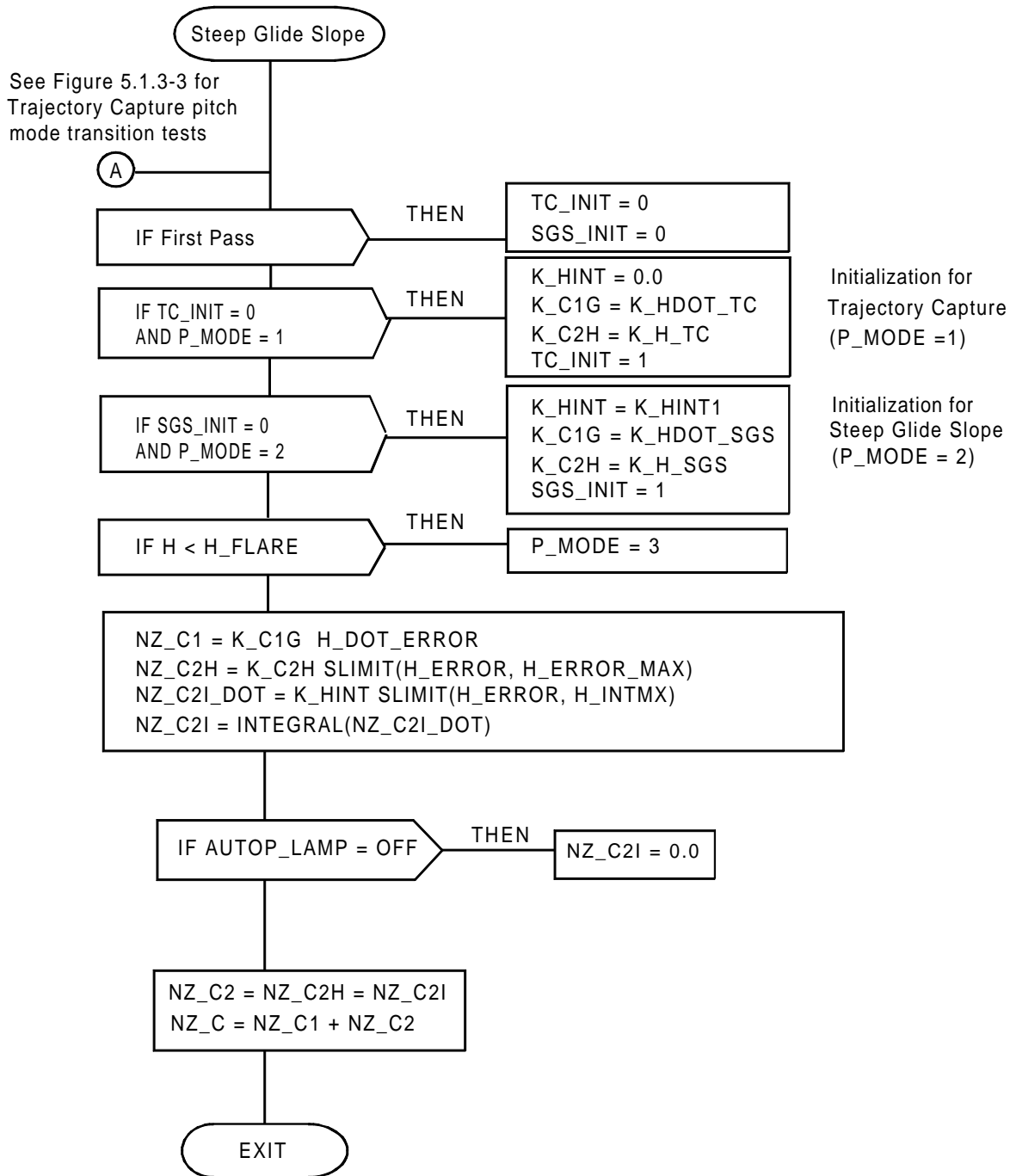


FIGURE 5.1.3-4. Approach/Landing Steep Glide Slope Functional Flow

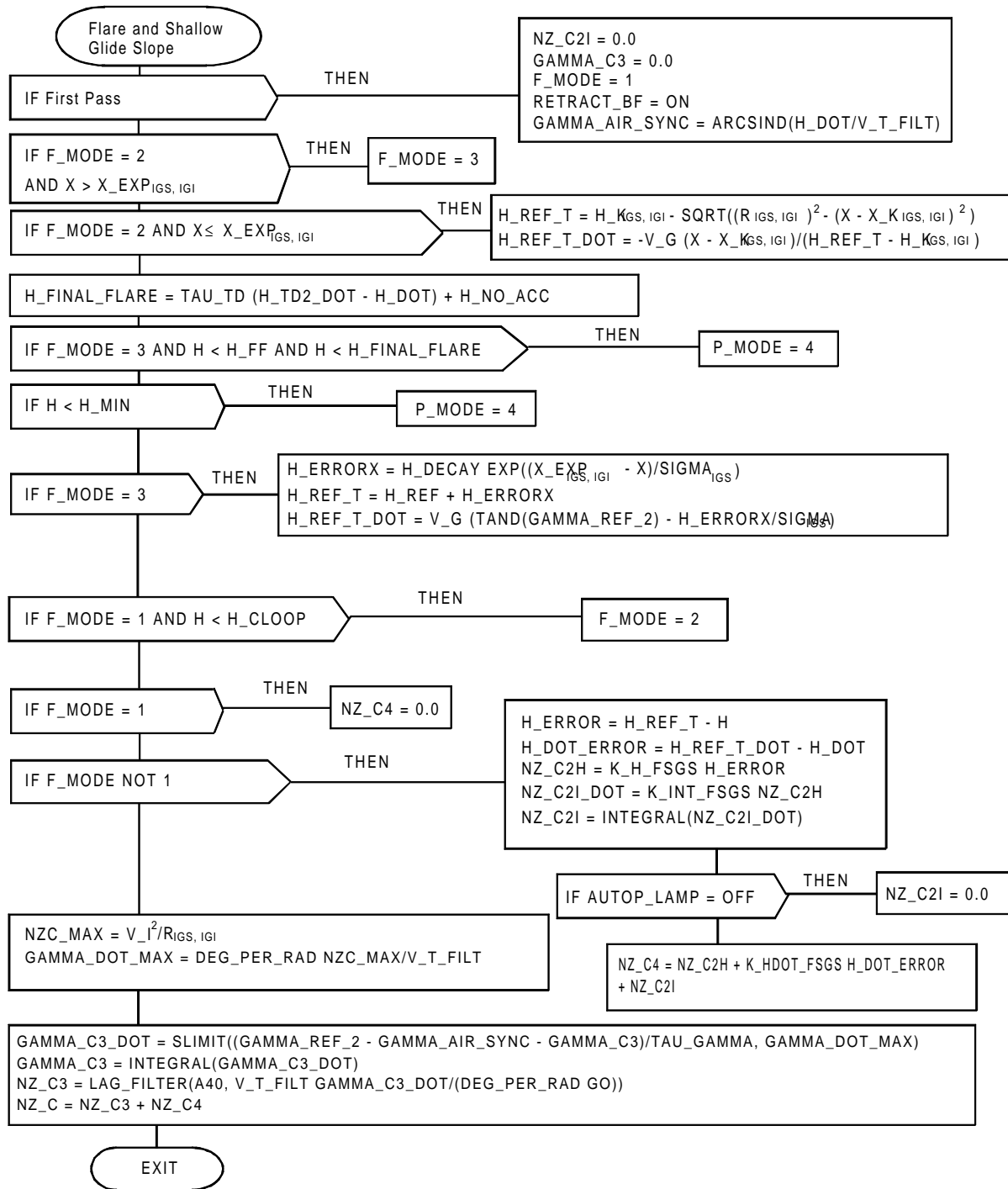


FIGURE 5.1.3-5. Approach/Landing Flare and Shallow Glide Slope Functional Flow

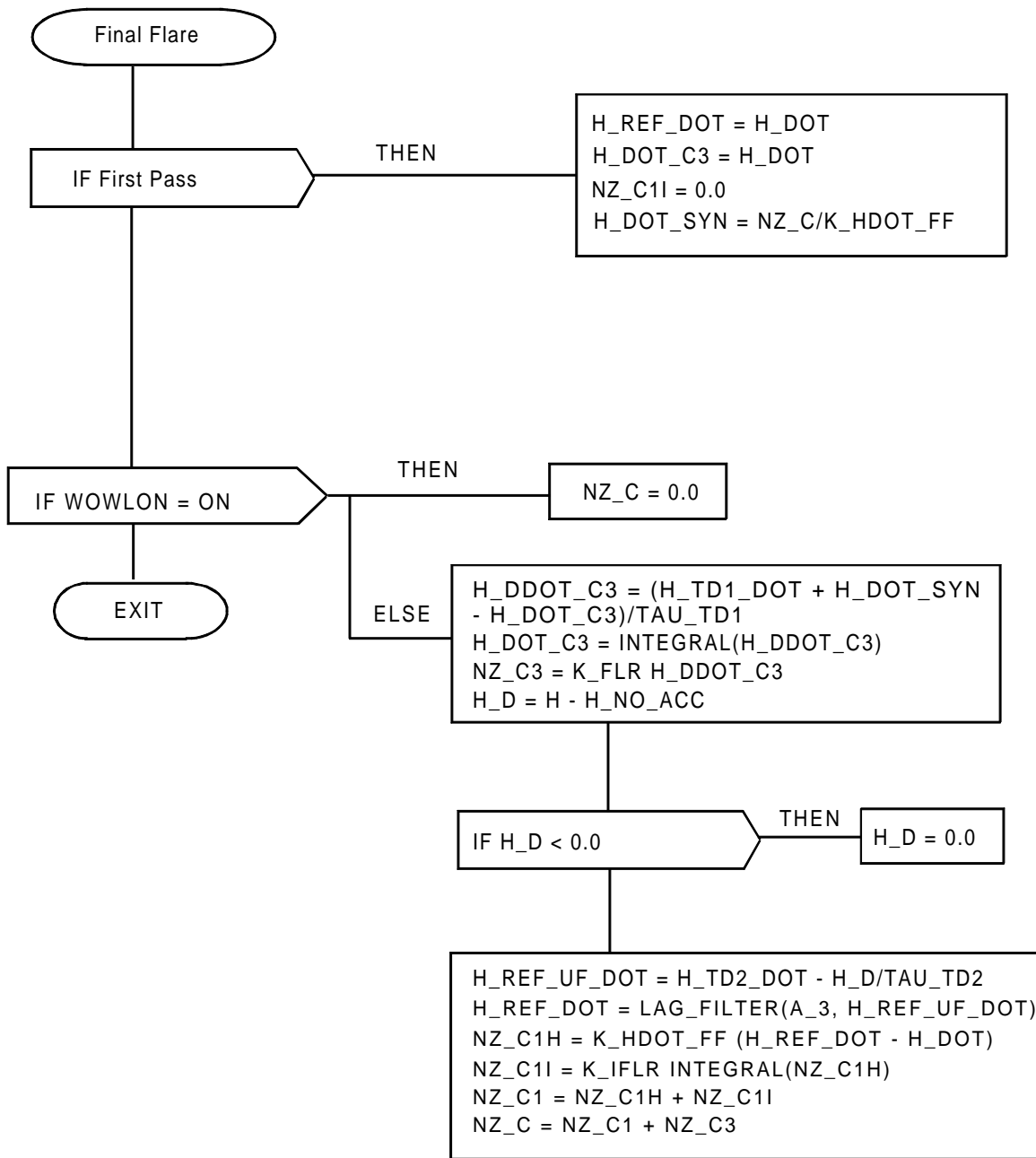


FIGURE 5.1.3-6. Approach/Landing Final Flare Functional Flow

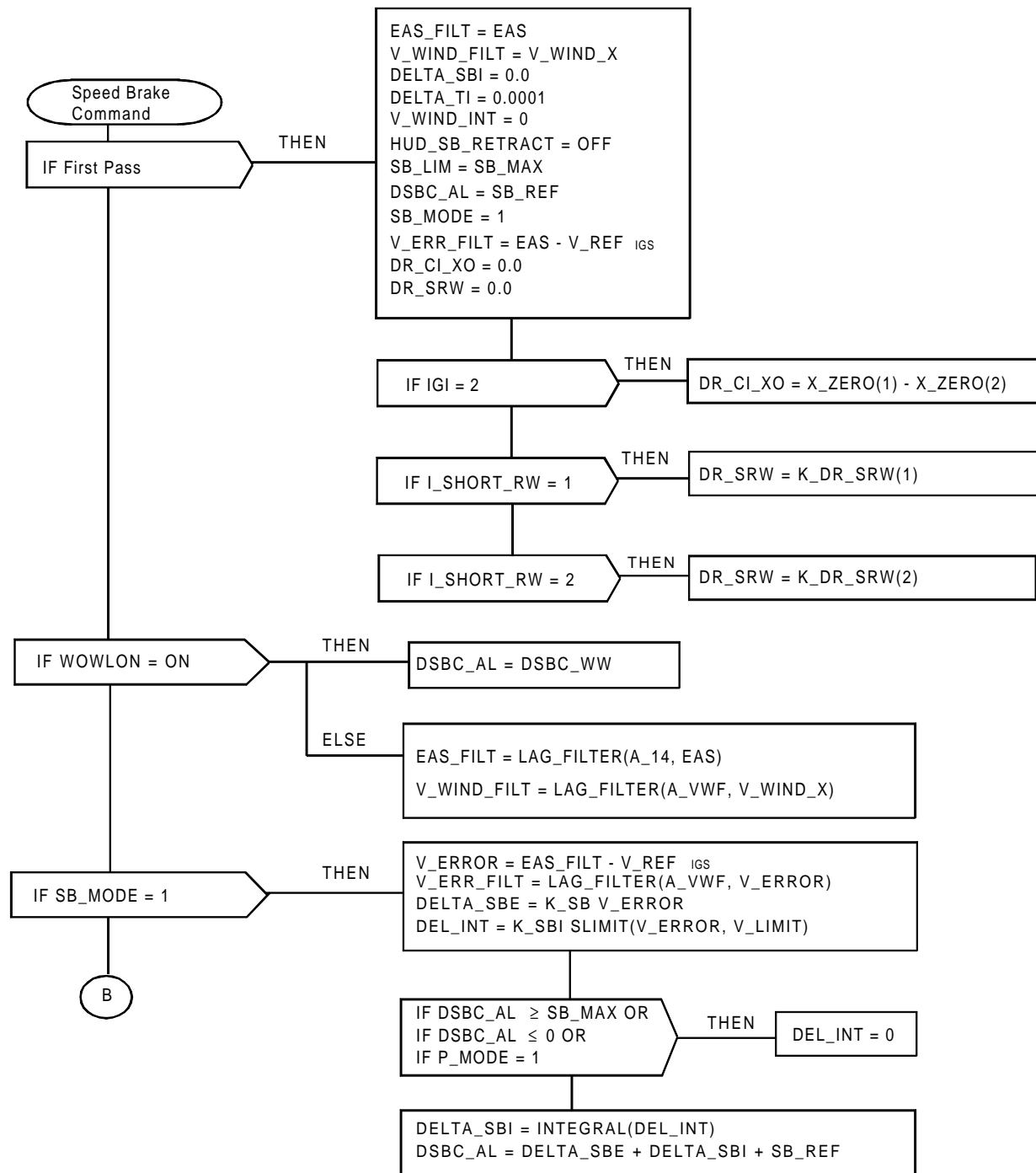


FIGURE 5.1.3-7.(1) Approach/Landing Speed Brake Command Functional Flow (Sheet 1 of 2)

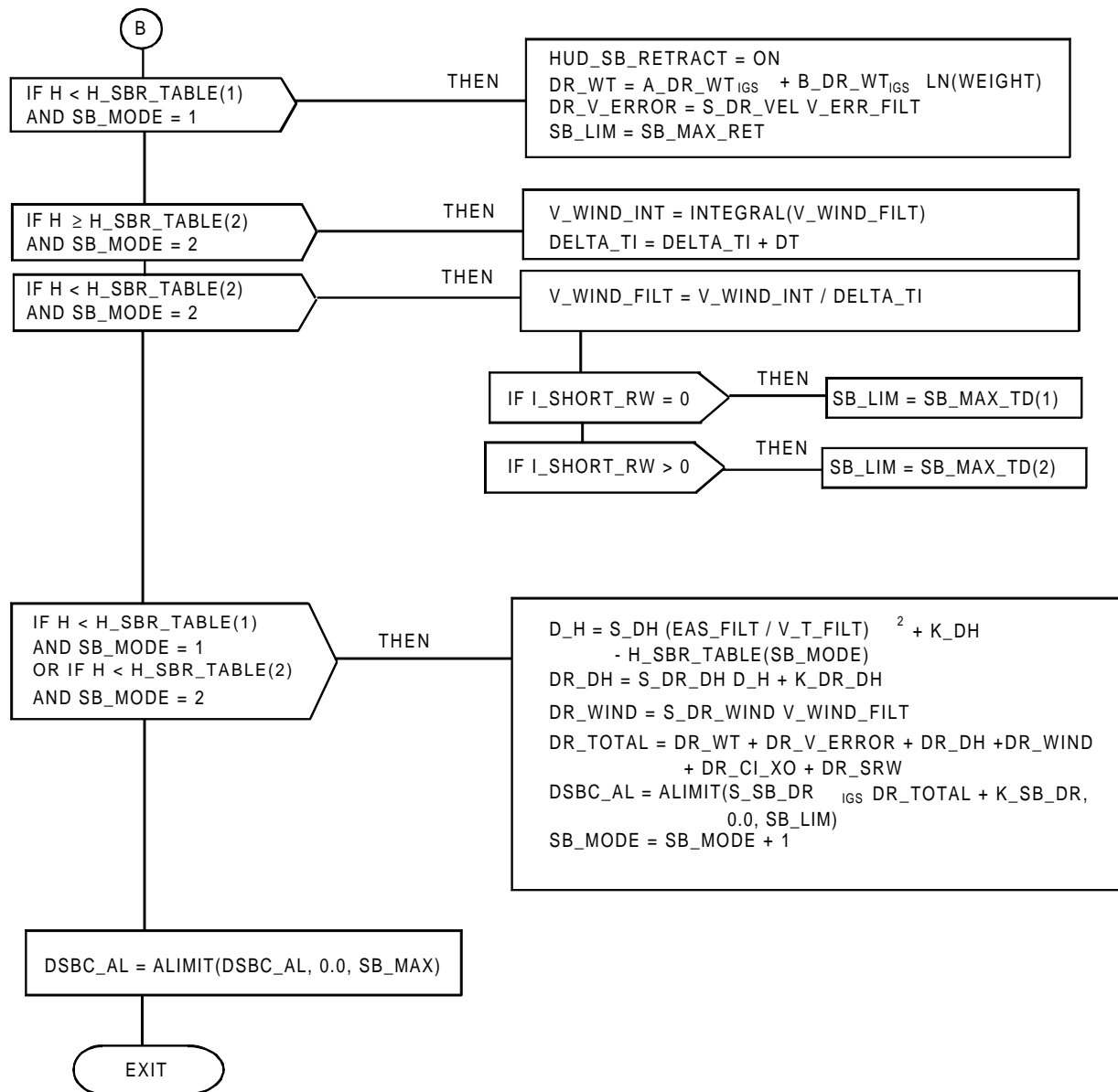


FIGURE 5.1.3-7.(2) Approach/Landing Speed Brake Command Functional Flow (Sheet 2 of 2)

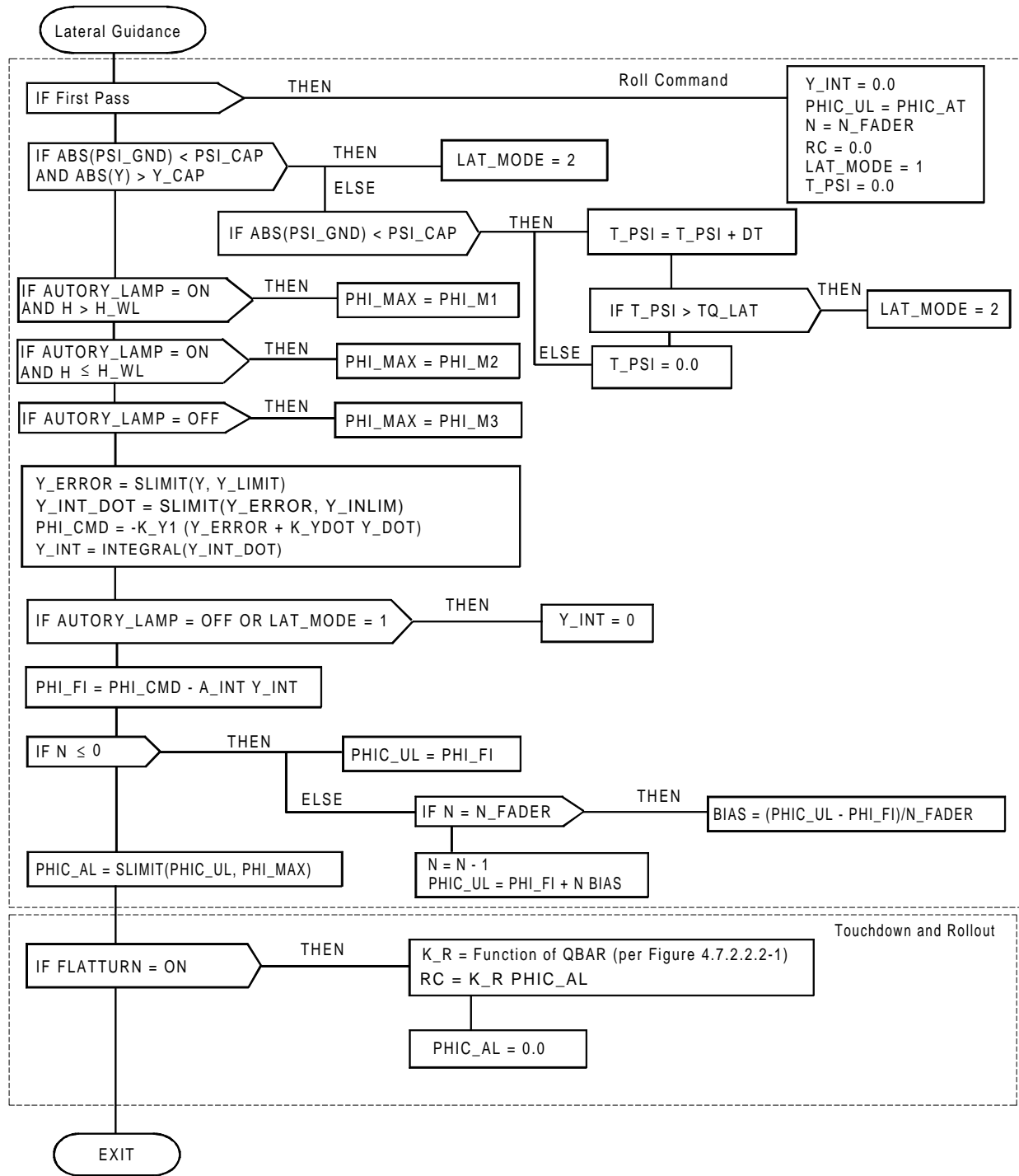


FIGURE 5.1.3-8. Approach/Landing Lateral Guidance Functional Flow

5.1.4 RTLS TAEM Guidance

The RTLS TAEM guidance parameters are shown in Table 5.1.4-1.

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
A	Temporary variable in ground track computation	GTP	0	F
ALPCMD	Angle of attack command	GRALPC	0	F
ALPH	Temporary variable in NZC computation	TGNZC	0	F
ALPHA_LF_ECAL	Load factor increment of ECAL pitch protection	GRTRN	0	F
ALPHA_MAX	ECAL maximum alpha limit	GRTRN	0	F
ALPHA_MIN	ECAL minimum alpha limit	GRTRN	0	F
ALPLL	Angle of attack lower limit	TGNZC	0	F
ALPNZLL	DNZCF lower limit based on ALPLL	TGNZC	0	F
ALPNZUL	DNZCF upper limit based on ALPUL	TGNZC	0	F
ALPUL	Angle of attack upper limit	TGNZC	0	F
ALPHA_UL	ECAL angle of attack upper limit for load factor protection	GRTRN, GRALPC	0	F
AMR	Alpha-Mach region used for ALPHA_MIN limit calculation	GRTRN	3	I
ARCAC	Acquisition turn arc length	GTP	0	F
ARCHA	Heading alignment turn arc length	GTP	0	F
AUTOP_LAMP_PAST	Past pitch axis mode indicator	TGTRAN	OFF	D
AUTORY_LAMP_PAST	Past roll/yaw axis auto mode indicator	TGTRAN	OFF	D
B	Temporary variable in ground track computation	GTP	0	F
BAILOUT_ARM	Bailout arm flag	TGSBC, TGPHIC	OFF	D
BAILOUT_BANK	Bailout roll control engaged flag	TGTRAN, TGPHIC	OFF	D
BAILOUT_PITCH	Bailout pitch control engaged flag	TGTRAN, TGNZC	OFF	D
CORNZ	Corrected normal acceleration	GRTRN	0	F
DEL RNG	Delta ground track range correction due to roll error	GTP	0	F
DGRALP	Increment to ALPCMD	GRALPC	0	F
DGRNZ	Phase 5 NZC increment based on max \dot{h}	GRALPC, GRTRN, GRNZC	0	F
DHDRRF	Tangent of reference flight path angle	TGCOMP, TGNZC	0	F

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
DNZC	Unlimited NZ command	TGNZC	0	F
DNZCD	Rate of change of DNZC	TGNZC	0	F
DNZCF	Filtered DNZC	TGNZC	0	F
DNZCL	Temporary variable in NZC computation	TGNZC	0	F
DNZLL	Minimum value of NZC	GRINIT, TGTRAN, TGNZC	0	F
DNZUL	Maximum value of NZC	GRINIT, TGTRAN, TGNZC	0	F
DPHI	Variable in roll command fader	TGPHIC	0	F
DPSAC	Heading error from tangency with HAC in ACQ phase	GTP, GRPHIC, TGPHIC	0	F
DPSACI	ECAL initial roll direction for high energy	GRPHIC	0	F
DPSACT	ECAL target heading error for high energy	GRPHIC	0	F
DPSACLMT	ECAL target DPSAC limit for high energy	GRPHIC	0	F
DPSAC_INIT	ECAL high energy heading error init flag	GRINIT, GRPHIC	OFF	D
DRCUB	Delta range used in altitude reference calculation	TGCOMP	0	F
DRPRED	RPRED + XALI	TGCOMP, TGNZC, TGTRAN	0	F
DSBC	Unlimited speed brake command	TGSBC	0	F
DSBC_AT	Speed brake command	GRSBC, TGSBC	0	F
DEF_ADO	Past value of DEF_AD	GRINIT, TGCOMP	OFF	D
DSBE	Component of DSBC due to QBERR	TGSBC	0	F
DSBI	QBERR integral term of DSBC	GRINIT, TGSBC	0	F
EAS_CMD	Equivalent airspeed command	TGCOMP	0	F
ECAL	ECAL logic ena/inh discrete	GRPHIC, GRTRN, GRALPC	OFF	D
EMAX	Energy over weight used to calculate EOWNZUL	TGNZC, TGCOMP	0	F
EMEP	Energy over weight used for MEP determination	TGCOMP, GRTRN, TGTRAN	0	F
EMIN	Energy over weight used to calculate EOWNZLL	TGNZC, TGCOMP	0	F

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
EN_ALPHA_BIAS	ECAL energy alpha bias	GRTRN	0	F
EN	Energy over weight reference	TGCOMP, TGNZC	0	F
EN_DELTA	ECAL EOW-EN DELTA	GRTRN	0	F
EN_DELTA_OLD	Previous value of EN_DELTA	GRTRN	0	F
ENLIMHI	ECAL high energy limit for pitch biasing	GRTRN	0	F
ENLIMLO	ECAL low energy limit for pitch biasing	GRTRN	0	F
EOW	Energy over weight	TGCOMP, GRTRN, TGTRAN, TGNZC, GRPHIC	0	F
EOWNZUL	DNZC upper limit based on EMAX	TGNZC	0	F
EOWNZLL	DNZC lower limit based on EMIN	TGNZC	0	F
ES	Energy over weight used for S–turn initiation	TGCOMP, GRTRN, TGTRAN, GRPHIC	0	F
EST	Energy over weight used for S–turn termination	TGCOMP, TGTRAN, GRPHIC	0	F
GDH	Gain on HDERR and HERROR in computing DNZC	TGNZC	0	F
GRALPR	Reference angle of attack	GRTRN, GRALPC	0	F
HDERR	Altitude rate error in computing DNZC	TGNZC	0	F
HDMAX	Maximum sink rate during alpha recovery	GRALPC	$(1-16^{-6})$ $\times 16^{63}$	F
HDREF	Reference altitude rate	TGNZC	0	F
HEADCR	Increment to predicted range due to heading error	GTP	0	F
HERROR	Altitude error from reference altitude	TGCOMP, TGNZC	0	F
HREF	Reference altitude	TGCOMP	0	F
IBNK	ECAL roll logic flag	GRPHIC	OFF	D
ICGUID	Flag to initialize pitch AMS on transition to BAILOUT_PITCH	TGNZC	OFF	D
ICNTR	ECAL pitch protection counter	GRTRN	0	I
ICUB	Index for HREF cubic selection	TGCOMP	0	I
IEL	Index for EN	TGCOMP	0	I
IEM	Index for EMEP	TGCOMP	0	I
IES	Index for ES	TGCOMP	0	I

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
IEST	Index for EST	TGCOMP	0	I
IGI	Ground intercept index	TGXHAC	0	I
IGRA	Alpha transition angle of attack command index	GRALPC	0	I
DGRNZT	Phase 5 Target Nz	GRALPC	0	F
DSBC_AT1	Incremented speedbrake command	GRSBC	0	F
DSBC_AT2	Scheduled speedbrake command	GRSBC	0	F
NZSW	Nz level at which Phase 6 to Phase 5 transition occurs	GRINIT GRTRN	NZSW1	F
INIT_PASS	RTLS TAEM guidance first pass flag	GREXEC, GRINIT	ON	D
IPHASE	TAEM guidance phase indicator	GREXEC, GRINIT, GTP, TGNZC, GRTRN, GRALPC, GRSBC, GRPHIC, TGTRAN, TGSBC, TGPHIC	6	I
IPPRTF	ECAL logic pitch protection flag	GRTRN, GRALPC	OFF	D
ISR	PFL roll command fader counter	GRINIT, TGPHIC	0	I
IRLPTF	ECAL logic roll protection flag	GRPHIC	OFF	D
ISNAPB	Flag to indicate roll angle has been “snapped” for bailout	TGPHIC	OFF	D
ISNAPP	Flag to indicate QBAR has been “snapped” for bailout	TGNZC	OFF	D
ITGTNZ	ECAL prebank initiation flag	GRALPC, GRPHIC	OFF	D
ITSW	Phase 6 to Phase 5 transition latch	GRTRN	0	I
MEDS_DPSAC	MEDS Display heading error	GTP	0	F
MEPALERT	Energy deficiency flag	GRINIT, GRTRN, TGTRAN	FALSE	D
NEP_FB	NEP/MEP flag	TGXHAC	ON	D
NZC	Normal acceleration command	GRNZC, TGNZC	0	F
NZTB	ECAL termal target NZ bias	GRALPC	0	F
PHAVG	Average roll angle during acquisition turn	GTP	0	F

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
PHIC	Unlimited roll angle command	TGTRAN, GRPHIC, TGPHIC	0	F
PHIC_AT	RTLS TAEM roll angle command	GRPHIC, TGPHIC	0	F
PHIC_ATS	“Snapped” roll angle for bailout	TGPHIC	0	F
PHILIM	Subsonic roll command limit	GRINIT, TGTRAN, TGPHIC, GRPHIC	0	F
ISTP4	Phase 4 S–turn flag	GRINIT, GRPHIC, GRTRN	0	I
PHIGN	ECAL roll limit for Qbar protection	GRPHIC	0	F
PHILIMIT	Roll command limit	TGPHIC	0	F
PHINZ2	ECAL roll limit for Nz protection	GRPHIC	0	F
PHIO	Previous value of PHIC during PFL	TGTRAN, TGPHIC	0	F
PSC	Vehicle position angle with respect to HAC center	GTP	0	F
PSHA	Heading alignment turn angle	GTP	0	F
PST	Heading to HAC tangency point	GTP	0	F
QBARD	Limited rate of change of QBAR	TGCOMP	0	F
QBARF	Filtered QBAR	GRINIT, TGCOMP, TGNZC	0	F
QBARS	“Snapped” QBAR for bailout	TGNZC	0	F
QBD	Filtered dynamic pressure rate	GRINIT, TGCOMP, TGNZC	0	F
QBERR	QBAR error	TGTRAN, TGSBC	0	F
QBG2	Variable gain used to compute QBNZLL and QBNZUL	TGNZC	0	F
QBLL	Reference dynamic pressure	TGCOMP	0	F
QBMNNZ	Lower limit on QBAR	TGNZC	0	F
QBMXNZ	Upper limit on QBAR	TGNZC	0	F
QBNZLL	Lower limit on NZC	TGNZC	0	F
QBNZUL	Upper limit on NZC	TGNZC	0	F
QBREF	Dynamic pressure reference	TGCOMP	0	F
RC	Range to HAC tangency point	GTP	0	F

Table 5.1.4-1. Initial Definition of RTLS TAEM Guidance Parameters				
Name	Description	Internal Use	Initial Value	Type
RCIR	Orbiter's radial distance from HAC center	GTP, TGTRAN, TGPHIC	0	F
RDOT	Radial rate deviation from HAC	TGPHIC	0	F
RERRC	HA phase PHIC component due to radial error from HAC	TGPHIC	0	F
RPRED	Predicted ground track range to the runway threshold	GTP, TGCOMP, TGTRAN	0	F
QBAR	Selected input dynamic pressure	TGCOMP	0	F
RT	Range-to-go where RDOT goes to zero	TGTRAN	0	F
RTAC	Radius of acquisition turn	GTP	0	F
RTAN	Straight line distance to HAC tangency	GTP	0	F
RW_IDO	Past value of runway index	GREXEC, GRINIT	0	F
S	Sign of roll command for S-turn	TGTRAN, TGPHIC	0	F
RPRED3	Prefinal initiation range	TGXHAC, TGTRAN	0	F
SMNZ1	Exponential term used to compute Phase 5 NZC	GRNZC	SMNZC1	F
SMNZ2	Integral term used to compute Phase 5 NZC	GRNZC	SMNZC2	F
SPSI	Temporary variable for determining sign of S-turn roll command	TGTRAN	0	F
TG_END	RTLS TAEM guidance termination flag	TGTRAN	0	F
XALI	MEP X coordinate of HAC center	GRINIT, TGXHAC, TGCOMP	0	F
XCIR	X distance from nearest HAC center	GTP, TGTRAN, TGPHIC	0	F
XFTC	Nominal X coordinate of HAC center	GRINIT, TGXHAC	0	F
XHAC	X coordinate of HAC center	TGXHAC, GTP	0	F
YCIR	Y distance from nearest HAC center	GTP, TGTRAN, TGPHIC	0	F
YERRC	Prefinal PHIC component due to lateral error	TGPHIC	0	F
YSGN	Sign of Y	GTP, TGTRAN, TGPHIC	0	F
V_PAST	Past value of V	GRINIT, TGCOMP	0	F

5.1.5 RTLS A/L Guidance

Refer to Section 5.1.3.

5.2 COORDINATE SYSTEMS

The coordinate systems used in entry, TAEM, and A/L guidance are described in the following paragraphs.

All position and velocity vectors used in guidance are defined in the runway coordinate system, described in Figure 4.3-1. The conversion of the state vector from earth-centered inertial (M50) to runway coordinates is done in navigation.

The altitude, altitude rate, and flight path angle definitions used are dependent on the guidance phase. During entry and TAEM, altitude above the landing site is defined as the altitude of the orbiter minus the altitude of the runway approach threshold above the Fischer ellipsoid. Altitude rate is the component of velocity along the local vertical, where the local vertical is a line normal to the Fischer ellipsoid through the vehicle c.g. During approach and landing, altitude and altitude rate are currently defined as the $-Z$ components of position and velocity in the runway coordinate system.

During TAEM and approach/landing, altitude is measured to the orbiter rear wheels, while during entry, altitude is to the nav base. Altitude rate and all velocity components are computed for the orbiter nav base.

For all major modes, altitude rate is positive for increasing altitude with time, and the flight path angle, γ , is defined as

$$\gamma = \sin^{-1} (\dot{H} / V), \left(-\frac{\pi}{2} \leq \gamma \leq +\frac{\pi}{2} \right)$$

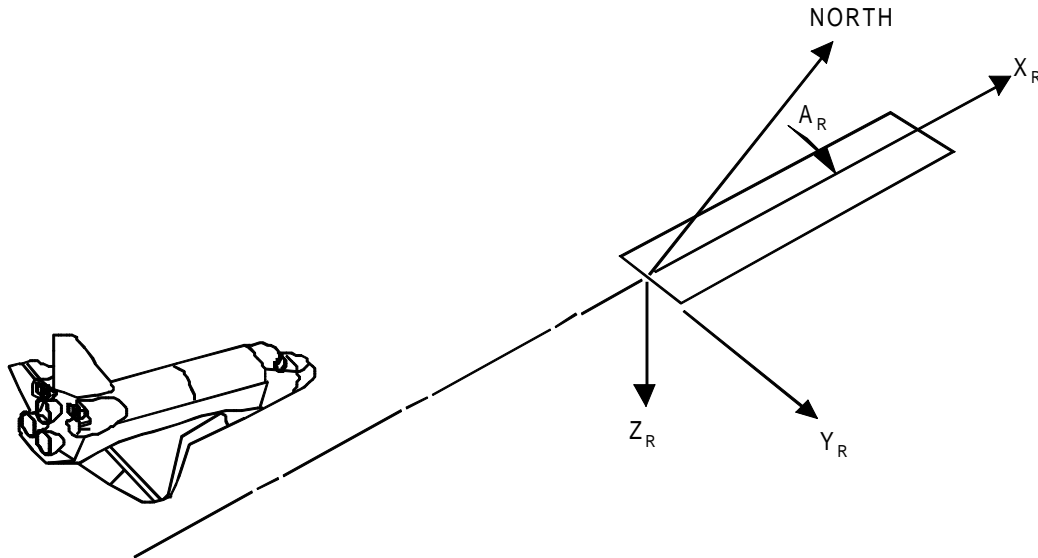
where

\dot{H} = altitude rate of the orbiter c.g.

V = ground relative velocity magnitude

The coordinate set of interest to guidance is the body axis coordinate system described in Figure 4.3-2.

The complete airframe orientation is defined by Euler angles with the rotation sequence, yaw (about the Z_b axis), pitch (about the Y_b axis), and roll (about the X_b axis). The reference orientation for the Euler angles is with the X axis pointed due north, wings level, and the Z_b axis pointed downward along the local vertical.



NAME: RUNWAY COORDINATE SYSTEM

ORIGIN: RUNWAY CENTER AT APPROACH THRESHOLD

CHARACTERISTICS: ROTATING, EARTH-REFERENCED

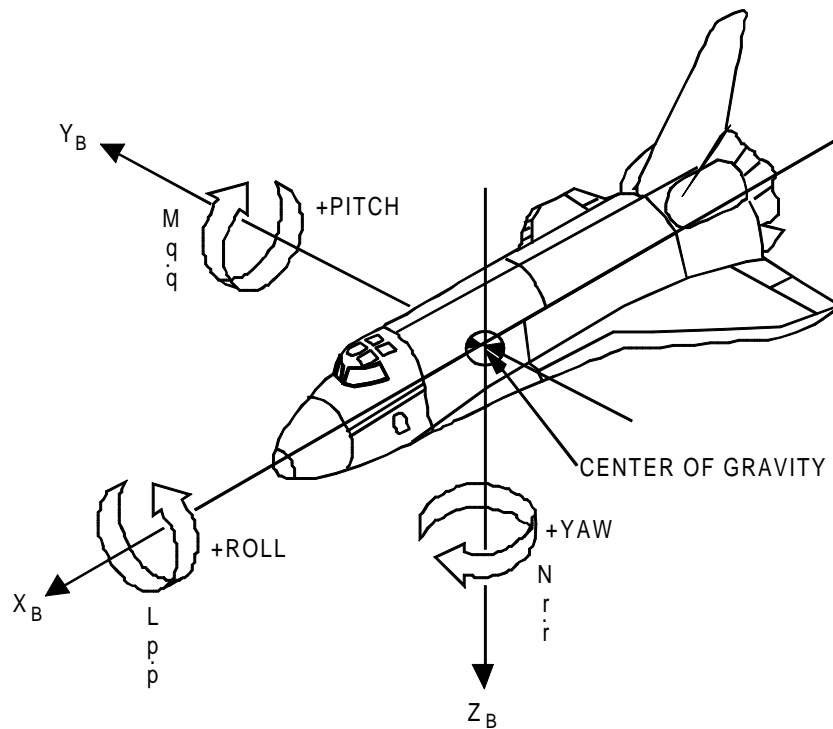
DESCRIPTION: Z_R AXIS IS NORMAL TO THE ELLIPSOID MODEL THROUGH THE RUNWAY CENTERLINE AT THE APPROACH THRESHOLD AND POSITIVE TOWARD THE CENTER OF THE EARTH

X_R AXIS IS PERPENDICULAR TO THE Z_R AXIS AND LIES IN A PLANE CONTAINING THE Z_R AXIS AND THE RUNWAY CENTERLINE (POSITIVE IN THE DIRECTION OF LANDING)

Y_R AXIS COMPLETES THE RIGHT-HANDED SYSTEM

A_R IS THE RUNWAY AZIMUTH MEASURED IN THE $X_R Y_R$ PLANE FROM TRUE NORTH TO THE $+X_R$ AXIS (POSITIVE CLOCKWISE)

FIGURE 5.2-1. Runway Coordinates



NAME: BODY AXIS SYSTEM

ORIGIN: ORBITER CENTER OF MASS

CHARACTERISTICS: ROTATING RIGHT-HANDED CARTESIAN SYSTEM. EARTH RELATIVE VELOCITY VECTORS, ANGULAR RATES, ANGULAR ACCELERATIONS, AND MOMENTS ARE EXPRESSIBLE IN THIS SYSTEM. THE ATTITUDE SEQUENCE IS YAW, PITCH, AND ROLL AROUND Z_B , Y_B , AND X_B AXES, RESPECTIVELY

DESCRIPTION: X_B AXIS LIES IN A PLANE PARALLEL TO THE PLANE OF SYMMETRY AND THROUGH THE CENTER OF MASS OF THE ORBITER. THE X_B AXIS IS PARALLEL TO THE PAYLOAD BAY CENTERLINE WITH THE POSITIVE SENSE THROUGH THE NOSE OF THE ORBITER

Z_B AXIS LIES IN THE SAME PLANE AS X_B AND IS NORMAL TO X_B WITH THE POSITIVE SENSE DOWN WITH RESPECT TO THE ORBITER FUSELAGE

Y_B AXIS COMPLETES THE RIGHT-HANDED COORDINATE SYSTEM

L, M, N: MOMENTS ABOUT X_B , Y_B , AND Z_B AXES, RESPECTIVELY

p, q, r: BODY RATES ABOUT X_B , Y_B , AND Z_B AXES, RESPECTIVELY

\dot{p} , \dot{q} , \dot{r} : ANGULAR BODY ACCELERATIONS ABOUT X_B , Y_B AND Z_B AXES, RESPECTIVELY

FIGURE 5.2-2. Body Axis Coordinates

5.3 GLOSSARY

This section presents a glossary of terms and abbreviations used in the main text of this report.

5.3.1 Definitions

ACQ – Acquisition phase of TAEM.

ANGLE OF ATTACK – The angle between the projection of the relative velocity vector onto the plane of symmetry and the orbiter X axis.

BANK ANGLE – The angle between the Z stability axis and the vertical plane containing the X stability axis.

BODY FLAP – An aerosurface used in conjunction with the elevon to trim the vehicle to the desired angle of attack.

DEADBAND – A zone within which there is no desired activity.

DOWNLINK – Data going from the vehicle to ground support facilities.

ECAL – East Coast Abort Landing

ELEVON – A dual purpose aerosurface that combines the pitching effect of elevators with the rolling effect of ailerons in a single control panel on each wing.

ENTRY POINT or ENTRY TARGET POINT – The point where the two heading alignment cylinders touch the extended runway centerline.

EQUIVALENT AIRSPEED – The airspeed at sea level that would produce the same dynamic pressure as the current true airspeed.

FLARE – A pitchup maneuver during approach and landing to decrease the rate of descent.

FLOATING POINT – A signed decimal number in which provisions are made for varying the location of the decimal point.

FUNCTION – An identifiable software element.

GTP – Ground track predictor function of TAEM guidance.

HA – Heading alignment phase of TAEM.

HAC – Heading alignment cone, an imaginary cone containing the nominal final turn flight path onto the runway centerline.

INTEGER – A signed whole number.

LATERAL – Translational motion in the Y body direction and rotation about the X and Z body axes.

LONGITUDINAL – Translational motion along the Z body axis and rotation about the Y body axis.

MACH (Number) – True airspeed divided by the velocity of sound.

OFF – Operational flight program – the total computer program in the orbiter general-purpose flight computer subsystem.

PFL – Prefinal approach phase of TAEM.

QBAR – Dynamic pressure.

RCO – Remote Control Orbiter – Unmanned contingency landing capability.

ROLL ANGLE – The angle between the Z body axis and the vertical plane containing the X body axis.

RTLS – Return to launch site abort.

SPEED BRAKE – The split rudder used to control orbiter speed by varying drag.

TAEM – Terminal area energy management.

UPLINK – Computer data sent from the ground support facilities.

UI – User interface – the software interface with the keyboard.

5.3.2 Acronyms and Abbreviations

AD	Air data
A/L	Approach and landing
AP or	
ATT PROC	Attitude processor
AT	Automatic TAEM
AUTO	Automatic
BF	Body flap
BFCS	Backup flight control system
CAS	Control augmentation system
CO	Checkout
CPDS	Computer program development specification
CSS	Control stick steering
DAP	Digital autopilot
DD	Dedicated display
DI	Display interface
DIP	Display processor
D&C	Displays and controls
EAS	Equivalent airspeed
EG	Entry guidance
F&SGS	Flare and shallow glide slope
FC	Flight control
FCOS	Flight computer operation system
FCS	Flight control system

FF	Final flare
FSSR	Functional subsystem software requirements
GN&C	Guidance, navigation, and control
GPC	General-purpose computer
GD	Guidance
HAC	Heading alignment cone
HAL	High-order articulated language
Hz	Hertz
I/O	Input/output
IMU	Inertial measurement unit
L/D	Lift/drag
LDG	Landing
MEP	Minimum entry point
MSBLS	Microwave scanning beam landing system
MSC	Moding, sequence, and control
NV or NAV	Navigation
NEP	Nominal entry point
OFFP	Operational flight program
OFT	Orbital flight test
PT	Pitch trajectory
RC	Roll command
RCO	Remote Control Orbiter
RCS	Reaction control system
RM	Redundancy management
SB	Speed brake
SBTC	Speed brake thrust control
SF	Selection filter
SGS	Steep glide slope
SM	System management
SP or SOP	Subsystem operating program
SW	Software
TAEM	Terminal area energy management
TBD	To be determined
TC	Trajectory capture
TD	Touchdown
TG	TAEM guidance
TN	Trajectory number
TRAJ	Trajectory
TRANS	Transition
UPP	User parameter processing

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WONG	Weight on nose gear
WOWLON	Weight on main wheels
wrt	With respect to

5.3.3 Units of Measurement

deg	Degrees
ft	Feet
ft/s, fps	Feet per second
g	Unit of acceleration
kt	Knots
lb	Pounds
lbm	Pounds mass
m	Meters
nmi	Nautical miles
psf	Pounds per square foot
rad	Radians
s, sec	Seconds

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APPENDIX R CHANGE AUTHORIZATION REFERENCES

R.1 CR REFERENCE SUMMARY

Table R.1-1. lists the paragraphs, tables (T), and figures (F) that have been changed as a result of approved change requests commencing with OI-26 up to the current OI. Changes incorporated prior to OI-26 are listed in the Historical Change Request Summary.

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	Title
N/A	92973	32	Reassign Effectivity of SCRS 92542D & 92743D to OI-32
4.5.2.2	93146B	33	Minor Doc Update to FSSRs 1, 2, and 16
4.5.2.2-1.(T)	92454A	29	OI-29 FSSR 1 Corrections
4.5.2.2-2.(T)	92355B	29	GPC Major Mode to MEDS
4.5.2.4	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.2.4-1.(T)	92355B	29	GPC Major Mode to MEDS
	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.2.4-2.(T)	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.2.5	92149	27	Entry Guidance Requirements Corrections for OI-27
4.5.2.8	92454A	29	OI-29 FSSR 1 Corrections
4.5.2.11-1.(T)	92354	27	Delete Erroneous TLM Destinations
4.5.2.11-2.(T)	92149	27	Entry Guidance Requirements Corrections for OI-27
4.5.2.13	92454A	29	OI-29 FSSR 1 Corrections
4.5.2.14	92480	28	Preclude Incorrect Roll Command Sign Reversals
	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.2.14-1.(T)	92619A	30	Correction CR for CR 92522D
	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.2.14-2.(T)	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.3	92354	27	Delete Erroneous TLM Destinations
4.5.3-1.(F)	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.3-2.(1)(F)	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.3-2.(4)(F)	92671A	30	Variable Low Alpha For Low-Energy Logic
4.5.4-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92542D	32	Deletion of LO2 Step Pressurization CMDS
	92067D	27	Three String GPS Capability
	90704F	28	DAP Hotstick Downmode Alert and Message
	92208C	28	GPS Issues for Correction on OI-28
	92225A	29	ET SEP Switch Default to Auto on a TAL Abort

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	92353D	29	Automated Alpha-Beta Management During Mated Coast & MM104
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
4.5.4-2.(T)	92354	27	Delete Erroneous TLM Destinations
	92355B	29	GPC Major Mode to MEDS
	92619A	30	Correction CR for CR 92522D
4.5.4-3.(T)	92671A	30	Variable Low Alpha For Low-Energy Logic
	93090E	33	Bearing Displays
4.5.4-5.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92069B	26B	Single-String GPS Documentation Cleanup
	92395F	28	Incorporate G on MEDS Displays
	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
4.6.2.3-1.(T)	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.6.2.4-1.(T)	90996G	26	ADI & HUD Error Display Integrator Mods
4.6.2.5	92454A	29	OI-29 FSSR 1 Corrections
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
4.6.2.5-1.(T)	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
4.6.2.6-1.(T)	92389C	29	Spiral HAC in TAEM Area Navigation
	92454A	29	OI-29 FSSR 1 Corrections
4.6.2.7-1.(T)	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.6.3-1.(T)	92067D	27	Three String GPS Capability
	92099B	27	Flight Path Angle RTLS Downlist Units Correction
	90704F	28	DAP Hotstick Downmode Alert and Message
	90914C	28	Delay MOV MPS Dump/Frcs Dump at MM602
	92353D	29	Automated Alpha-Beta Management During Mated Coast & MM104
	92389C	29	Spiral HAC in TAEM Area Navigation

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
4.6.3-2.(T)	92332D	30	Add Theta Limits Bracket to MEDS ADI Displays
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92619A	30	Correction CR for CR 92522D
	93018B	32	Blank HAC Turn Angle on PFD at Heading Alignment
	93023D	32	OI-32 Remote Control Orbiter Capability
	93090E	33	Bearing Displays
	90996G	26	ADI & HUD Error Display Integrator Mods
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
4.6.3-3.(T)	93090E	33	Bearing Displays
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	92389C	29	Spiral HAC in TAEM Area Navigation
	92432A	29	BFS Cleanup for Spiral HAC CR 92389C
4.6.3-5.(T)	93090E	33	Bearing Displays
	92389C	29	Spiral HAC in TAEM Area Navigation
	92395F	28	Incorporate G on MEDS Displays
4.7.1	92332D	30	Add Theta Limits Bracket to MEDS ADI Displays
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
4.7.2	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.2-1.(T)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	92551B	30	Short Field Landing Speedbrake Upgrade
4.7.2.1	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1-1.(T)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.2.1.1	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93135	33	Correction to OI-33 Remote Control Orbiter Capability Enhancement - SCR 93100C
4.7.2.1.1-1.(T)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	93135	33	Correction to OI-33 Remote Control Orbiter Capability Enhancement - SCR 93100C
4.7.2.1.1-1.(F)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93135	33	Correction to OI-33 Remote Control Orbiter Capability Enhancement - SCR 93100C
4.7.2.1.1-2.(T)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.2.1.2	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.3	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.4	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.4-1.(T)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.5	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.6	92551B	30	Short Field Landing Speedbrake Upgrade
	92677	30	Correction to CR 92551B
	92752B	30	Documentation Update to A/L Guid Speed Brake Cmd Functional Flow
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.1.6-1.(T)	92551B	30	Short Field Landing Speedbrake Upgrade
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93135	33	Correction to OI-33 Remote Control Orbiter Capability Enhancement - SCR 93100C
4.7.2.1.6-2.(T)	92551B	30	Short Field Landing Speedbrake Upgrade
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.2	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.2.1	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.2.2.2	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.3-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92067D	27	Three String GPS Capability
	92099B	27	Flight Path Angle RTLS Downlist Units Correction
	90704F	28	DAP Hotstick Downmode Alert and Message

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	90914C	28	Delay MOV MPS Dump/FRCS Dump at MM602
	91050C	28	Improved Fault Tolerance to Executing Beep Trim Derotation
	92355B	29	GPC Major Mode to MEDS
	92450C	29	Documentation Clean-up for CR 92389
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92551B	30	Short Field Landing Speedbrake Upgrade
	93090E	33	Bearing Displays
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.3-2.(T)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.3-3.(T)	92551B	30	Short Field Landing Speedbrake Upgrade
	92938B	32	BFS HUD Processor
	93090E	33	Bearing Displays
	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
4.7.3-4.(T)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.7.3-5.(T)	92395F	28	Incorporate G on MEDS Displays
	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
4.8.1	90724D	28	OPS 6 Entry ECAL Automation
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	93087E	33	RTLS ET Separation Improvements
4.8.2.1-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92264B	28	Correction CR for CR90724D - OPS 6 Entry ECAL Automation
4.8.2.3	90724D	28	OPS 6 Entry ECAL Automation
4.8.2.3-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	92454A	29	OI-29 FSSR 1 Corrections
	93012B	32	PASS 6X TRAJ Display Enhancement
	93018B	32	Blank HAC Turn Angle on PFD at Heading Alignment Phase
4.8.2.3-2.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	92454A	29	OI-29 FSSR 1 Corrections
4.8.2.4-1.(T)	90996G	26	ADI & HUD Error Display Integrator Mods
4.8.2.5	92522D	30	Overhaul MEDS Composite Flight Instrument Display
4.8.2.5-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92389C	29	Spiral HAC in TAEM Area Navigation
	92454A	29	OI-29 FSSR 1 Corrections
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
4.8.2.6	90724D	28	OPS 6 Entry ECAL Automation
	93115A	33	ECAL Energy Compensation
4.8.2.6-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92389C	29	Spiral HAC in TAEM Area Navigation
	93115A	33	ECAL Energy Compensation
4.8.2.6-2.(T)	90724D	28	OPS 6 Entry ECAL Automation
	93115A	33	ECAL Energy Compensation
4.8.2.8	90724D	28	OPS 6 Entry ECAL Automation
	92264B	28	Correction CR for CR90724D - OPS 6 Entry ECAL Automation
	92550B	30	ECAL Automation Updates
4.8.2.8-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	92550B	30	ECAL Automation Updates
4.8.2.8-2.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92454A	29	OI-29 FSSR 1 Corrections
	92550B	30	ECAL Automation Updates
4.8.2.9-2.(T)	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
4.8.2.10	90724D	28	OPS 6 Entry ECAL Automation
	92264B	28	Correction CR for CR90724D - OPS 6 Entry ECAL Automation
	92454A	29	OI-29 FSSR 1 Corrections
	92550B	30	ECAL Automation Updates
	92685A	30	Correction to CR 92550B, ECAL Automation Update
4.8.2.10-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92550B	30	ECAL Automation Updates
4.8.2.10-2.(T)	90724D	28	OPS 6 Entry ECAL Automation

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92550B	30	ECAL Automation Updates
4.8.2.11	90724D	28	OPS 6 Entry ECAL Automation
	93087E	33	RTLS ET Separation Improvements
4.8.2.11-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	93087E	33	RTLS ET Separation Improvements
4.8.2.12	90724D	28	OPS 6 Entry ECAL Automation
	92264B	28	Correction CR for CR90724D - OPS 6 Entry ECAL Automation
	92305	28	Correction for NZ Limiting of Roll Command for CR90724D
	92550B	30	ECAL Automation Updates
	93146B	33	Minor Doc Update to FSSRs 1, 2, and 16
4.8.2.12-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
4.8.2.12-2.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92305	28	Correction for NZ Limiting of Roll Command for CR90724D
	92550B	30	ECAL Automation Updates
4.8.2.13-1.(T)	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
4.8.2.15-1.(T)	92454A	29	OI-29 FSSR 1 Corrections
4.8.2.16-1.(F)	92454A	29	OI-29 FSSR 1 Corrections
4.8.3-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92099B	27	Flight Path Angle RTLS Downlist Units Correction
	90704F	28	DAP Hotstick Downmode Alert and Message
	90724D	28	OPS 6 Entry ECAL Automation
	90914C	28	Delay MOV MPS Dump/FRCS Dump at MM602
	92353D	29	Automated Alpha-Beta Management During Mated Coast & MM104
	92355B	29	GPC Major Mode to MEDS
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92389C	29	Spiral HAC in TAEM Area Navigation
	92392C	29	Doc-Only Corrections for OI-29 CRs 92329E, 92364D, and 92369B
	92404B	29	Preserve MECO Vi, Altitude, & Altitude Rate in MM104
	92450C	29	Documentation Clean-up for CR 92389

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	Title
4.8.3-2.(T)	92332D	30	Add Theta Limits Bracket to MEDS ADI Displays
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92619A	30	Correction CR for CR 92522D
	93023D	32	OI-32 Remote Control Orbiter Capability
	93087E	33	RTLS ET Separation Improvements
	93090E	33	Bearing Displays
	90996G	26	ADI & HUD Error Display Integrator Mods
	90724D	28	OPS 6 Entry ECAL Automation
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
4.8.3-3.(T)	92454A	29	OI-29 FSSR 1 Corrections
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
	90724D	28	OPS 6 Entry ECAL Automation
	92389C	29	Spiral HAC in TAEM Area Navigation
	92432A	29	BFS Cleanup for Spiral HAC CR 92389C
	92454A	29	OI-29 FSSR 1 Corrections
	92550B	30	ECAL Automation Updates
	93090E	33	Bearing Displays
	93115A	33	ECAL Energy Compensation
4.8.3-5.(T)	93155B	33	Bearing Displays Correction
	91051K	26B	Streamlined Shuttle GPS Capability
	92395F	28	Incorporate G on MEDS Displays
	82389C	29	Spiral HAC in TAEM Area Navigation
	92332D	30	Add Theta Limits Bracket to MEDS ADI Displays
4.9.1	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
	93100C	33	OI-33 Remote Control Orbiter Capability
4.9.2	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.9.2-1.(T)	93100C	33	OI-33 Remote Control Orbiter Capability
	92551B	30	Short Field Landing Speedbrake Upgrade
4.9.3-1.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92099B	27	Flight Path Angle RTLS Downlist Units Correction
	90704F	28	DAP Hotstick Downmode Alert and Message
	90914C	28	Delay MOV MPS Dump/FRCS Dump at MM602

Table R.1-1. CR Reference Summary

Paragraph	CR No.	OI	Title
	91050C	28	Improved Fault Tolerance to Executing Beep Trim Derotation
	92355B	29	GPC Major Mode to MEDS
	92389C	29	Spiral HAC in TAEM Area Navigation
	92450C	29	Documentation Clean-up for CR 92389
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	92551B	30	Short Field Landing Speedbrake Upgrade
	93012D	32	PASS 6X TRAJ Display Enhancement
	93090E	33	Bearing Displays
	93100C	33	OI-33 Remote Control Orbiter Capability
4.9.3-3.(T)	92551B	30	Short Field Landing Speedbrake Upgrade
	92938B	32	BFS HUD Processor
	93090E	33	Bearing Displays
4.9.3-4.(T)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
4.9.3-5.(T)	91051K	26B	Streamlined Shuttle GPS Capability
	92395F	28	Incorporate G on MEDS Displays
	92389C	29	Spiral HAC in TAEM Area Navigation
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
	93090E	33	Bearing Displays
5.1	92752B	30	Documentation Update to A/L Guid Speed Brake Cmd Functional Flow
5.1.1-1.(T)	92454A	29	OI-29 FSSR 1 Corrections
	92671A	30	Variable Low Alpha For Low-Energy Logic
5.1.2-1.(T)	92522D	30	Overhaul MEDS Composite Flight Instrument Display
5.1.3	92752B	30	Documentation Update to A/L Guid Speed Brake Cmd Functional Flow
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-1.(T)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
5.1.3-1.(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-1.(1)(F)	92752B	30	Documentation Update to A/L Guid Speed Brake Cmd Functional Flow
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-1.(2)(F)	92752B	30	Documentation Update to A/L Guid Speed Brake Cmd Functional Flow

Table R.1-1. CR Reference Summary			
Paragraph	CR No.	OI	Title
5.1.3-2.(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-3.(F)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93135	33	Correction to OI-33 Remote Control Orbiter Capability Enhancement - SCR 93100C
5.1.3-4.(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-5.(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-6.(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-7.(1)(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-7.(2)(F)	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.3-8.(F)	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
	93015C	32	Documentation Update to Approach/Landing Guidance Functional Flow
5.1.4-1.(T)	90724D	28	OPS 6 Entry ECAL Automation
	92264B	28	Correction CR for CR90724D - OPS 6 Entry ECAL Automation
	92364D	29	Just-In-Time Flight Design (JITFD) I-Load Uplink Expansion
	92454A	29	OI-29 FSSR 1 Corrections
	92522D	30	Overhaul MEDS Composite Flight Instrument Display
5.3.1	92550B	30	ECAL Automation Updates
	90724D	28	OPS 6 Entry ECAL Automation
5.3.2	93100C	33	OI-33 Remote Control Orbiter Capability Enhancement
5.3.3	92454A	29	OI-29 FSSR 1 Corrections

R.2 HISTORICAL CHANGE REQUEST SUMMARY

Table R.2-1. is an historical record of approved change requests incorporated since the initial baseline up to OI-25. Change requests commencing with OI-26 are reformatted and listed in the CR Reference Summary.

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
2071		Double Ramp QBar Reference for TAEM
2166		General Entry Update
2212		Revised Entry Guidance Controller Drag Gain
2213		Entry Guidance Deletion of Drag Integral Feedback Lockout for RW Redesignation and CSS Mode
2363		Cubic Plus Linear TAEM Altitude-Range Reference
2417B		Revision of Entry Displays
2607		Update to D&C Book II
12019		Standard FSSR Functions
12223		Revised TAEM Guidance EMAX Equation
12272		Entry Guidance Modification to Roll Limit Logic
12273		Entry Guidance h Bias Limit and Zero Capability
12274		Entry Guidance Modification to Lateral Deadband Logic
12275		Entry Guidance Increase in Angle-of-Attack Command Segments
12320		Correction to TAEM Guidance Energy References
12336		I-Load Update
12337		I-Load Update
12338		I-Load Update
12339		I-Load Update
12353B		Entry Displays Simulation Update
12361A		Vertical Situation 1 and Situation 2 Display Changes
12442A		Integrated Entry, Ascent, and Orbit Navigation Interface Signal Requirements
12443		I-Load Update
12466		Entry Guidance Variable Name Revision
12471A		TAEM Guidance NAVDAD/Default QBar Select Logic
12478		Update to Vehicle Mass Definition
12500A		Autoland Guidance Make Work Changes
12705		ADI Roll Error Needle E/L
12848H		Optional TAEM Targeting (OTT)
12850		Entry Guidance Angle-of-Attack Modulation

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
12948		I-Load Update
12993		I-Load Update
12994		I-Load Update
19010		I-Load Update
19038		I-Load Update
19045A		I-Load Update
19054		Load Update
19069A		I-Load Update
19070		Correction to Entry Displays Altitude Rate Reference
19078A		RTLS TAEM Guidance NAVDAD/Default QBar Select Logic
19134		Detailed Requirements to Support CR2212
19135		Detailed Requirements to Support CR2213
19164A		I-Load Value Updates for Cycle 2 Software Build (Ref Only)
19182		Autoland Slapdown and Rollout I-Load Changes for STS-1
19199		GRTLS TAEM Supersonic Speed Brake Schedule
19201		I-Load Update
19209		RTLS TAEM Guidance Load Relief/Alpha Transition Logic
19256A		TAEM HAC Selection
19259		GRTLS A/L Guidance Weight Input
19300		FSSR Update 2
19370		GRTLS TAEM S-Turn Capability for Alpha Transition Phase
19452B		I-Load Correction Necessary for March 19, 1979, Release
19500		FSSR Update 3
19545		Sign Change to Entry Guidance FSSR
19549A		Mod to Prevent TAEM to A/L Transition Lock-Out
19557		Scrub GRTLS Guidance by Deleting Glide Slope Index
19560A		I-Load Updates as a Result of IBM Testing
19576		Corrections to GRTLS TAEM Guidance for CR19078A
19581B		Corrections to I-Load Paper Baseline, STS-1
19700		FSSR Update 4
19900		FSSR Update 5
19966		TAEM Guidance S-Turn Initiation Correction for Optional Left Hand Turn CR19256A
29042A		Clarification of Detailed Requirements for Entry Guidance FSSR
29094D		MPAD I-Load Update 2 for STS-1, Cycle 3

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
29117C		MPAD I-Load Update 3 for STS-1, Cycle 3
29170A		Required Approach/Land Guidance Mod, STS-3
29267A		Res 180 for GRTLS TAEM's S-Turn Test, STS-2
29295		GRTLS Range Predictor I-Load (Ref Only)
29300		FSSR Update 6
29336B		I-Load Designator Correction (Ref Only)
29367B		GRTLS Guidance I-Load Cleanup, STS-1
29399C		Streamline Vert Sit Dip, STS-2 (18)
29471B		HFE Overrun Definition, STS-1 (16)
29500		FSSR Update 7
29579B		Definition of Constants Approach Landing Guid, STS-2 (18)
29650A		CR Implement Baseline May, 1980, Report 1037
29657C		Redefinition of Entry Guidance I-Load (Ref Only) Cycle 3, STS-1
29660A		Current Vehicle Mass Update (18)
29685A		Definition of Entry Guidance I-Load Parameters (18)
29699A		D&C Usage of Guidance I-Load (Ref Only)
29774B		Horiz Sit. Spec – Use guid XHAC
29912B		Angle-of-Attack Modulation (STS-3)
29999A		Optional TAEM Targeting Rewrite
39000		FSSR Update 9
39073B		Vert Sit. Dip Changes – TAEM
39087A		Head-up Display (HUD)
39104C		S-Turn Energy Line Modification (Ref Only)
39184E		STS-2 Cycle 1 MPAD I-Loads (Ref Only)
39237		Shift Nominal Energy—GRTLS
39238		Speedbrake Command in GRTLS
39264E		HUD Autoland Monitor Format (IDD only)
39365F		HUD PROC I/O Cleanup
39387		Change to Entry I/L DLAPLM (Ref Only)
39399		TAEM Prefinal NZC Limits (Ref Only)
39400		FSSR Update 1 (R19)
39401A		Transatlantic Abort Landing (TAL) (STS-3)
39467A		DR Closeout—Document Cleanup
39507		TAEM Prefinal Ramp Bank Limit
39508A		TAEM Speed Brake Ramp Limit—OTT (STS-7)

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
39510B		OTT Energy Symbol Display (STS-7)
39511B		HSD Changes—OTT
39595		CR Implementation Baseline—August, 1981
39602B		STS-3 Cycle 2 Orb/Ent I-Loads (STS-3; Ref Only)
39640		FSSR Update 2 (R19)
39658E		STS-4 Cycle 1 MPAD I-Loads (STS-4; Ref Only)
39683C		OTT/TAEM Prefinal Bank Gains
39684B		TAEM Prefinal Bank Gains (STS-3; Ref Only)
39764		Incorrect Value for N_FADER (STS-3; Ref Only)
39775		STS-4 Cycle 1 Update—Ent Guid (STS-3; Ref Only)
39790		CR Implementation Baseline—November, 1981
39795A		GRTLS HDOTNZ Compensation
39806A		Calculation of CALP2(12) (STS-3)
39815A		Automated PTI
39950		FSSR Update 3 (R19)
39980A		CR Implementation Baseline—February, 1982
59043E		STS-6 Cycle 2 Nav/Ent I-Loads (STS-6 Only; Ref)
59050		FSSR Update 4 (R19)
59081A		Eliminate HDMAX I-Load
59178C		Speed Brake Annunciation (Ref Only)
59204		GRTLS Subsonic SB Limit (STS-5; Ref)
59207B		HUD Altitude Monitor Make Work (STS-6)
59212A		STS-5 Autoland Improvement (STS-5; Ref)
59220		CR Implementation Baseline – July, 1982
59314C		OTT Corrections
59333A		GRTLS S_TURN Alpha Profile
59350		FSSR Update 6 (R19)
59375		CR Implementation Baseline – September, 1982
59342A		OTT Modes for Energy Management (IL Ref Only)
59512		STS-7 PTI I-Load Correction (19.7 Ref Only)
59556		TAEM NZ Gains (IL Ref Only)
59574		GRTLS HDOT NZ Compensation
59641		GRTLS Energy Management (Ref Only)
59650		CR Implementation Baseline – March, 1983
59750		FSSR Update 8 (R19) and Update 2 (R20)

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
69042B		Doc Roll Cmd Range
69151A		TAEM Speed Brake Ramp LIM-OTT (Ref Only)
69192D		Appr and Lndg Guid Updt – GLC0
69193B		Appr and Lndg Guid Updt – GL30 (I-Loads Only)
69194B		Appr and Lndg Guid Updt – GL10 (I-Loads Only)
69195C		Appr and Lndg Guid Updt – ZS00 (I-Loads Only)
69196B		Appr and Lndg Guid Updt – ZFH0 (I-Loads Only)
69270		Appr and Lndg Guid Updt – A2R0 (I-Loads Only)
69588		Cleanup of CR 69120
69623		STS-14 Only Descent I-Loads (Ref Only)
79499		FSSR Update 5
79790A		CR Implementation Baseline – November, 1985
79842C		Inadvertent Mode Transitions
79844G	20	Body/Flap Update
89125		Errata STS 83-0001A
89137C		Delete HUD 2 (Autoland) FMT
89250B		Bailout Control System
89272B		GRTLS Guidance Activation
89301C		Clarify MM603/305 Guide
89442G		Elevon Limit During Slapdown
89460		STS 83-0001B OI-8B Errata B/L
89461A		FSSR STS 83-0002B 8B Errata B/L
89474B		Auto NZ for Contingency Abort
89484C		Entry/TAL Guidance Enhancements
89503		FSSR STS 83-0015B 8B Errata B/L
89599C		Clean Up Level B GN&C Document
89620A		TGNZC I-Load / Constants
89647B		FSSR STS 83-0001B Errata Update
89672A		STS 83-0014B Volume 1 PCN-1 Errata
89740B		FSSR-7 OI-8B PCN-1 Errata
89805		Errata Change--CR 89665B, Page 3 and IDD
89979F	22	TAEM Guidance Energy Speedbrake Control
89990E	21	Single Engine Auto Contingency Abort
90152D	22	Contingency Abort TAL Low-energy Logic
90185A	20	Add CR Field to FSSR I/O Tables

Table R.2-1. Historical Change Request Summary		
CR No.	OI	CR Title
90302B	22	Entry Downlist Additions
90374C	20	Automated FSSR Constants
90476D	25	Wraparound Yaw Jet System w/PTI Effector
90545A	23	Entry Guidance Requirements Doc. Update
90690A	24	Deletion of EQTN MSID Column from K-Load FSSR Tables
90705H	25	3 Engine Out Auto Contingency
90790	24	Add Memory Configuration to the FSSR I-Load Tables
90814C	24	Add Description of Database Generated FSSR Parameter Tables
90815B	24	FSSR Book 1 & 20 Documentation Changes
90881A	25	FSSR STS83-0001 Documentation Changes
90960E	25	HAC Initiation Predictor and Position Error Displays
90964	25	Interface Clarification for 3 Engines Out-CR 90705H
90966A	24	Deletion of the Qualifier from the FSSR I-Load Tables
91066D	25	Standardize the FSSR Correlation Tables
92027B	25	TDMS-2 Required FSSR Changes